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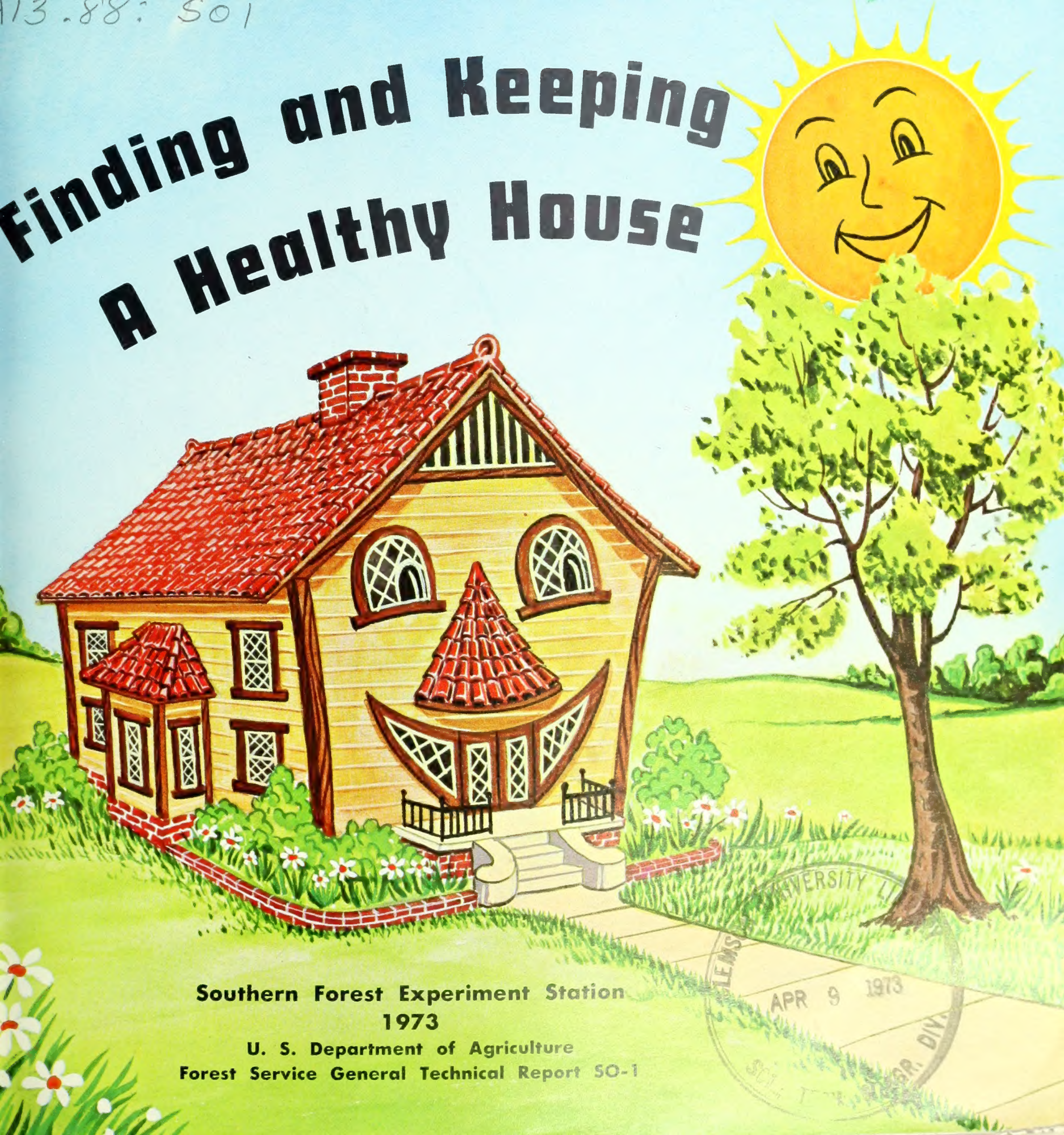
Finding and Keeping A Healthy House



Southern Forest Experiment Station
1973
U. S. Department of Agriculture
Forest Service General Technical Report SO-1

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Finding and Keeping a Healthy House

R. C. Biesterfeldt, T. L. Amburgey, and L. H. Williams

house is the average family's most expen- and important possession. It stands be- n the family and the world, and it will inue to do so as long as it stays healthy. ng a sick house, one that has a serious of decay or insect damage, can be a big But preventive medicine is no great chore well-constructed house. This booklet pro- s tips for selecting a healthy house and ceeping it that way.

Gulfport, Mississippi, years of research he Southern Forest Experiment Station demonstrated that good construction is ntial for excluding decay, termites, or r structural pests. Unfortunately, con- ction practices are not always the best, many people do not know how to maintain houses. As a result, houses often fail utlive their mortgages without costly re- s. The annual costs of termite damage and rol exceed $500 million in the United es. Estimates of losses to wood decay are available, but the costs, including outlays epairs, probably are as high as those for ites.

buyer is looking for a house that is in- d with termites or weakened by rot, but y a buyer gets just that. A termite inspection is required before certain types of home mortgages can be obtained, but for the most part the buyer must depend upon himself or his agent to find a healthy house. In a poorly constructed house, damage may not be visible. The buyer, therefore, should give careful attention to design features as well as signs of insects or decay.

Many buyers who would carefully inspect an old house for evidence of decay and structural pests fail to consider these wood destroyers when choosing a new house. Their confidence is often misplaced. If it is not properly protected, the sapwood lumber used in new homes is highly susceptible to decay and insects. If poor construction makes the wood vulnerable, damage almost certainly will occur in just a few years. In one sense, an old house is less of a risk. It has stood the test of time. If it is healthy now it will probably remain so with proper maintenance.

In this booklet, the destroyers of wood in houses are discussed in order of probable occurrence. Decay comes first because it is the most likely form of damage in most houses. Termites and other wood-destroying insects are covered next, and wood-nesting insects last.

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DECAY

Wood decay is caused by small plants called fungi. These organisms cannot colonize or decay wood that has a moisture content of less than about 30 percent. The wood in a properly constructed and maintained home is safe because its moisture content is seldom above 15 percent. The prescription for preventing decay is simple: KEEP WOOD DRY.

That prescription is not always easy to follow, however. The siding of a house is exposed to rain that blows against it. When there is a large temperature difference between the inside and outside of a house, condensation can occur within the walls. Soil conducts water and can easily moisten wood in contact with it or directly above it to a point where decay is possible. Plumbing leaks can make wood inside the home vulnerable.

One must strive to keep wood dry at all times, because wood soaks up water and retains it for long periods. An occasional soaking during heavy rains will supply ample water for decay during the period between rains.

Wood that will become wet can be protected by treating it with preservatives. To assure long-term protection of wood, the preservative must be applied under pressure. If the wood is in contact with the ground, only pressure treatment is satisfactory. Decay resistance of pieces that will occasionally become moist can be increased slightly by brushing on a preservative, and soaking gives some additional protection. The appropriate chemical for treatment depends upon the wood's purpose. Some chemicals give off harmful odors, precluding their use indoors. Others cause paint to peel. The use for the treated wood should be specified when it or the preservative is purchased.

Even the fungi that cause what is called "dry-rot" cannot feed upon wood that has a moisture content below 30 percent, but they can conduct water from wet to dry portions of wood through structures called rhizomorphs. The primary water-conducting decay fungus in the United States is *Poria incrassata.* Since it brings moisture from one portion of a house to another, it can destroy all the wood in a building very rapidly—possibly within 2 years. Although this much destruction does not occur often, it is well to remember that it is possible, and that this fungus can grow wherever ordinary decay fungi can grow.

Mold and stain fungi also attack wood. Molds grow mainly on the surface but may penetrate the outer sapwood; the discoloration they cause can be removed by light sanding. Stain fungi penetrate the outer layers of sapwood and cause discoloration that cannot be removed. Both molds and stains feed upon wood. By themselves, they do not decay or weaken the wood, but by penetrating its tissues they increase its capacity to absorb and hold moisture. Thus, they increase the likelihood of decay. In addition, some people are allergic to the spores of mold fungi.

Wood decays very slowly when the temperature is below 40°F. Building deterioration, therefore, is more rapid in the South than in the North. Decay is also more rapid in humid than in dry regions. The organisms that cause decay, however, are present throughout the United States.

Designing for Dryness

When buying a house or planning alterations, remember that designs which permit wood to become wet invite decay. Moisture comes from soil as well as from rain.

Foundation sill plates, the lowest wood members of your house, should be well above the soil level around the entire perimeter of your house. Wood siding should be at least 8 inches above grade. With concrete slab construction, a portion of the slab should be visible on all sides of the house. Homeowners often invite decay by raising the level of the soil at the side of the house in order to plant flowers.

Embedding wood in concrete that is near the soil is also dangerous. If wood is laid on a concrete slab, there should be a moisture barrier under or on the slab. Where no barrier is present, the wood should be pressure-treated with preservatives. Posts resting on concrete floors can be protected by placing them on raised bases.

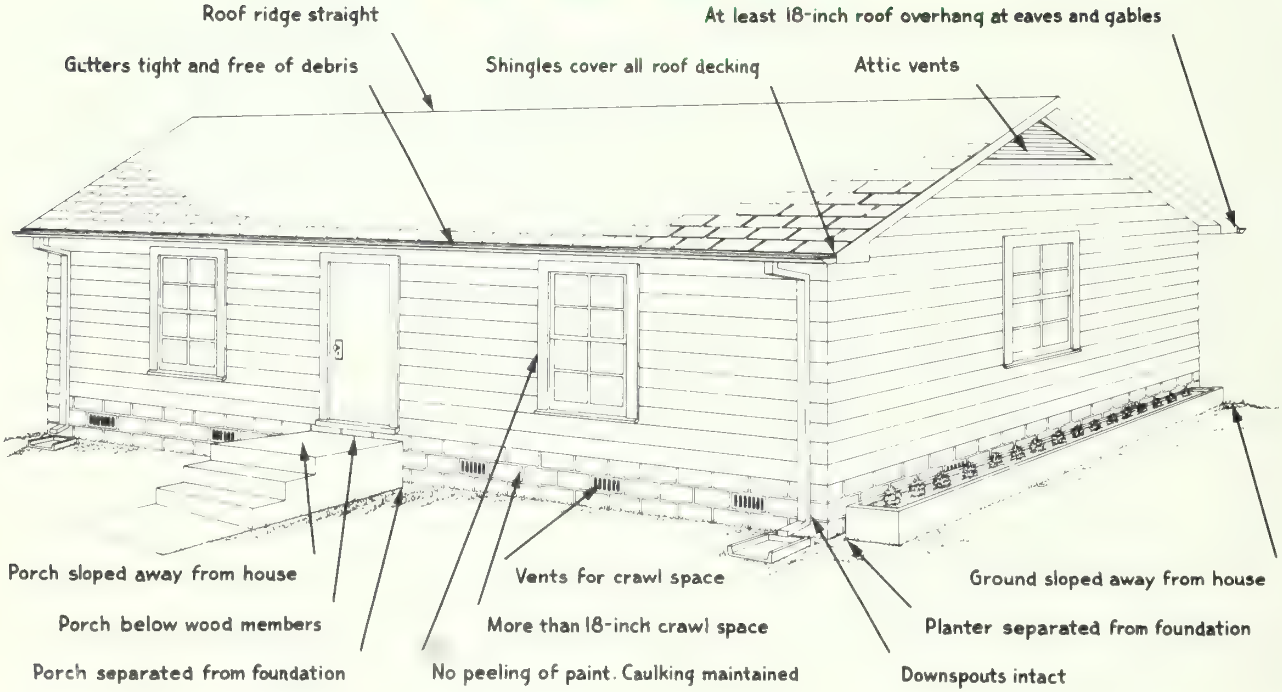
Water drainage away from the house is very important. Check for drainage by looking for puddles after a heavy rain. If the site is not level, subsurface tile drains may have to be installed on the upslope side to direct water around rather than under the house.

Crawl spaces under houses should be elevated at least 18 inches (preferably 2 feet), and they should be ventilated and protected from soil water. Even though the water table is many feet down, soil can transmit large quantities of water to the surface. In the shade beneath a house, uncovered soil will cause high humidities, and condensation may moisten wood foundation members and subflooring. To prevent this, it is recommended that the soil be covered with an impervious substance (moisture barrier) such as polyethylene or roll roofing. In addition, the level of the soil beneath the house should always be higher than that of the surrounding area. If it is not, puddles will develop beneath the house and the impervious layer will be more a hazard than a help if water is permitted to accumulate on top of it. The crawl space should have at least 4 wall ventilators located near the corners. The combined ventilating area of the openings should be at least 1/150 of the area underneath the house if the ground surface is bare, and 1/1,500 of the area under the house if the ground surface is covered with a moisture barrier.

In houses with basements, all below-grade portions of the foundation walls should be waterproofed on the outside. One method is to apply asphalt and cover it with polyethylene while it is still tacky.

The price of rain seepage.

YES!

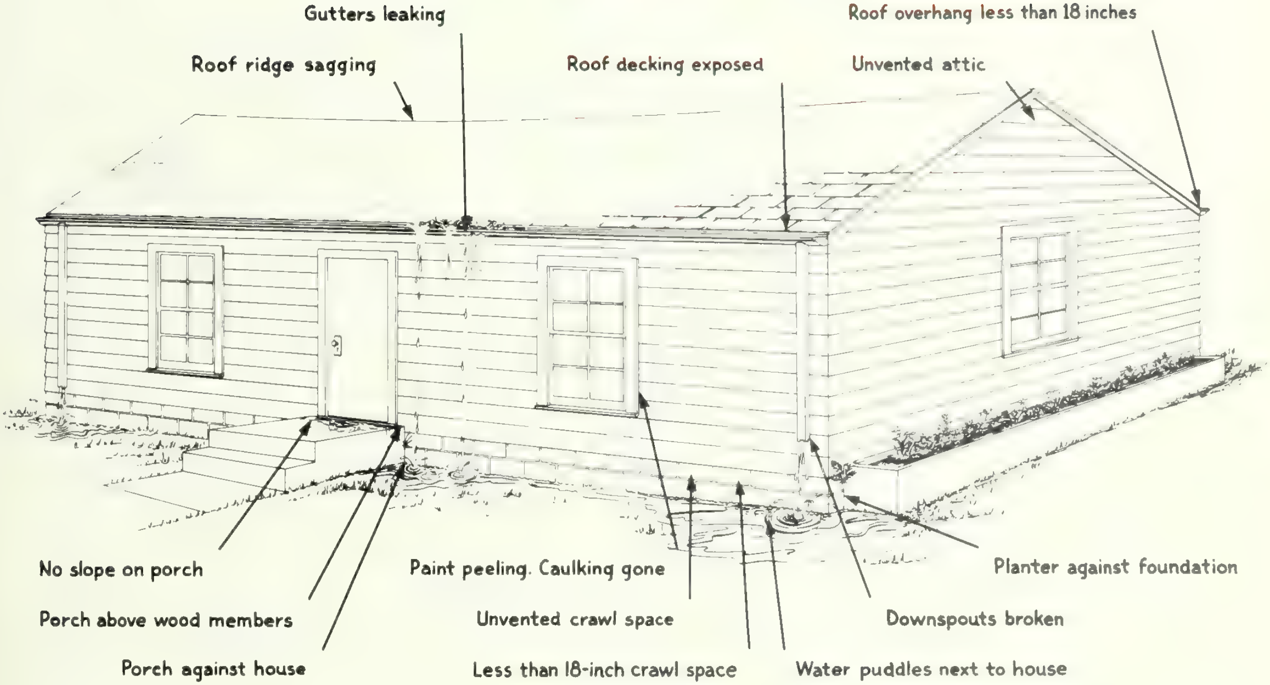

Roof ridge straight
Gutters tight and free of debris
Shingles cover all roof decking
Attic vents
At least 18-inch roof overhang at eaves and gables
Porch sloped away from house
Porch below wood members
Porch separated from foundation
Vents for crawl space
More than 18-inch crawl space
No peeling of paint. Caulking maintained
Ground sloped away from house
Planter separated from foundation
Downspouts intact

Earthfilled structures, such as porches, patios, and flower planters, present a very high decay hazard if they are in contact with the foundation and if the level of fill is above the foundation sill plates. Such structures should be separated from the foundation by 1 to 2 inches. In existing filled porches in contact with the foundation, the fill should be removed from the area adjacent to the house. The surface of patios and porches should be sloped away from the house.

Sufficient roof overhang is particularly important for protecting siding, windows, and doors from rainwater. In most parts of the United States 18 inches are sufficient, but 30 inches may be needed in areas of high rainfall such as the Gulf Coast and much of the Pacific Coast. This overhang is necessary at both gables and eaves. It prevents water from running down the siding except when high winds accompanies a rain.

Caulking is needed around doors and windows. When the culking dries and cracks, it must be replaced.

NO!



Gutters and downspouts prevent water from running down or splashing against siding. If they are not kept clear and free of leaks, however, gutters can be more of a hazard than a help. Water can back up in them and soak fascia boards and siding. Downspouts should direct water away from the house.

Attic vents at eaves and gables prevent moist air from accumulating. Roofs without gables (hip roofs) should have ventilators near their peaks. In warm, humid climates it is also advisable to install attic ventilating fans.

Roof leaks can cause very extensive decay in a short time. Leaks near the center of the roof are usually spotted and repaired promptly because they lead to ceiling damage inside the house. Those near the edge of the roof often go unnoticed for long periods, causing decay of decking and fascia boards. Asphalt shingles are often installed so that roof decking is exposed between shingle tabs at the eaves. A complete layer of shingles should extend beyond all edges of the roof. Metal flashing at the lower edge of the roof is also helpful.

Gaps between shingles near the roof edge can lead to decay.

Condensation is a troublesome source of moisture that can be avoided through placement of vapor barriers and through proper ventilation. It is caused by warm, moist air passing over a cooler surface. In cold climates, moisture barriers should be placed on the warm side (inside) of insulated walls and ceilings. Polyethylene directly behind the wall board is very effective. In existing homes, an impermeable paint applied to inside walls will greatly reduce the amount of water moving into them. In warm, humid regions condensation is sometimes associated with air conditioning. Insulated walls that permit free passage of water vapor are relatively safe.

Complete paint films or stains containing a wood preservative and water repellent should be maintained on all exposed wood surfaces. Paint is not a preservative, but it protects wood from intermittent wetting. Peeling paint and nail pulling indicate that wood is getting wet, that decay is likely to occur.

In warm, moist climates molds may develop on the paint. On the Gulf Coast, where mildew is very common, fungicides can be mixed with paint to protect it. Many of the fungicides are highly poisonous, however, and they should be used with great caution.

In general, architectural frills or novel forms of construction should be studied carefully before they are adopted. They may provide entrance points or pockets in which moisture can remain long enough for decay to get started. Lumber takes in water most readily through exposed ends, as in joints.

Paint peels from wood that is getting wet. If decay is not present, it soon will be.

Caulking around windows prevents rain seepage.

Ample roof overhang protects siding. Attic vents prevent condensation.

Indoor Water Sources

Plumbing leaks, even very small ones, eventually lead to decay of the wood that becomes wet. Often the cost of repair is quite high before any damage is apparent.

Leaks in caulking around **bathtubs, shower stalls**, and **sinks** may permit large quantities of water to enter walls and flooring. In some cases the flooring beneath a bathtub has given way before the owner knew that any major damage was occurring. When buying a home investigate carefully around showers, sinks, and tubs. Flooring that is no longer level, does not fit tightly against baseboards, or feels spongy when walked on is a sign of advanced decay.

Cold water pipes that accumulate condensation or "sweat" for long periods should be insulated. The same is true for **air conditioning ducts.**

Improperly vented appliances can release considerable moisture inside the house. Clothes driers, for example, should be vented to the outside of the house and not into a crawl space, garage, or attic.

DESTRUCTIVE INSECTS

The average homeowner is probably more fearful of subterranean termites than of decay. Even though he is not familiar with termite control techniques, he is aware of the termite threat. He may not know that other insects also can severely damage the wood in his home. Drywood termites and certain beetles as well as subterranean termites feed upon the wood in houses. And carpenter ants and carpenter bees may nest in wood, causing some damage and a major nuisance. The homeowner or buyer should learn to recognize the damage of these insects, and he should know a little about the insects and the proper methods for controlling them.

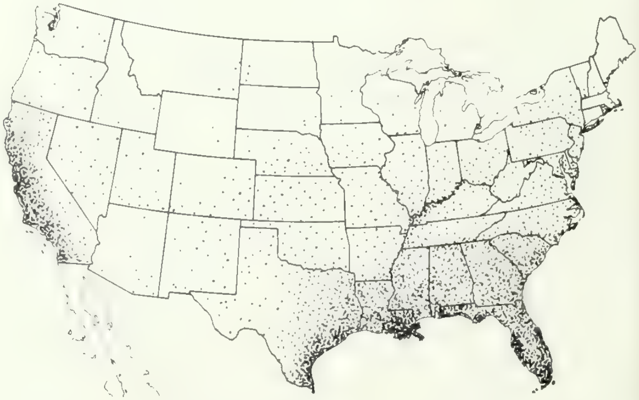
SUBTERRANEAN TERMITES

These insects have earned their notoriety by causing costly damage in much of the United States. But, as will be shown, infestations can be prevented through proper building design, construction, and maintenance. If a colony is discovered in the home, there is no cause for panic. Effective control methods are known.

Subterranean termites live in large social groups called colonies. They got their name because workers and soldiers, the most common forms in colonies, spend their entire lives either underground or in completely enclosed galleries in wood that is under attack.

These insects require high humidity, which they maintain with moisture from the soil or from a dependable supply in the wood under attack. The danger of attack and the speed at which destruction occurs increase with average temperature and with moisture availability.

Subterranean termites are found in most tropical and temperate regions of the world. The accompanying map indicates where they are a major cause for concern.



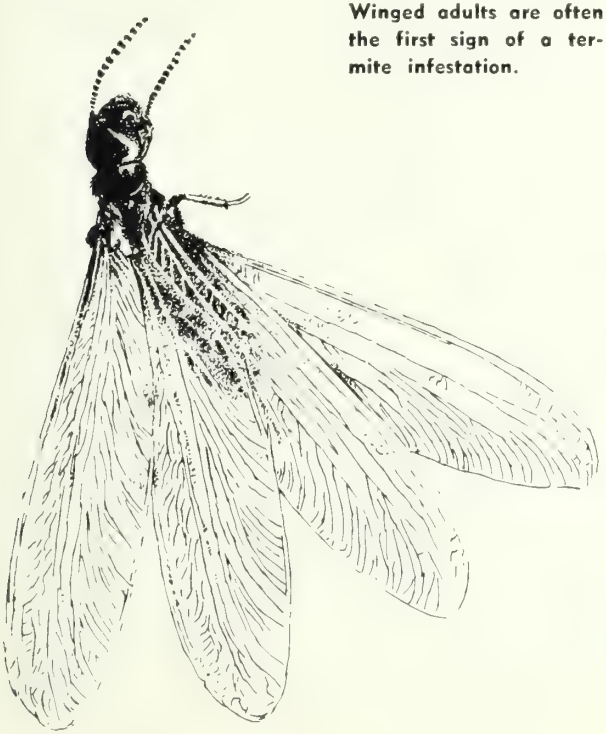
Relative hazard of termite attack in the United States.

Recognizing Termites and Their Work

Because subterranean termites must avoid contact with dry air, their work often goes unnoticed until damage is serious or until the colony produces a flight of winged adults called a swarm.

In the East, **swarming** occurs most frequently on sunny spring days. Flights may occur in almost any month in warm, humid parts of the country, however.

Winged termites inside the house are almost a sure sign of trouble. They are fairly easy to recognize. They have yellow-brown to black bodies and two pairs of long, whitish, translucent wings of **equal size.** The reproductive forms of ants, with which winged termites are often confused, have two pairs of wings of unequal size. Termites have **thick waistlines,** whereas ants have hourglass figures.

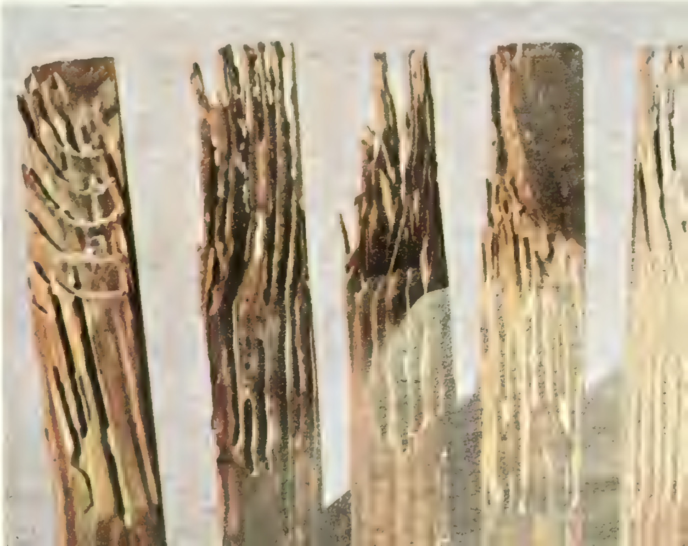


Winged adults are often the first sign of a termite infestation.

Soon after the flight the wings are discarded by adult termites. **Discarded wings** are often found beneath doors or windows and around light fixtures, because the winged forms are attracted to light. Their presence inside the house is a strong indication of infestation. Because there are many colonies outside in stumps and the like, adults seen near the house are not necessarily a sign of trouble.

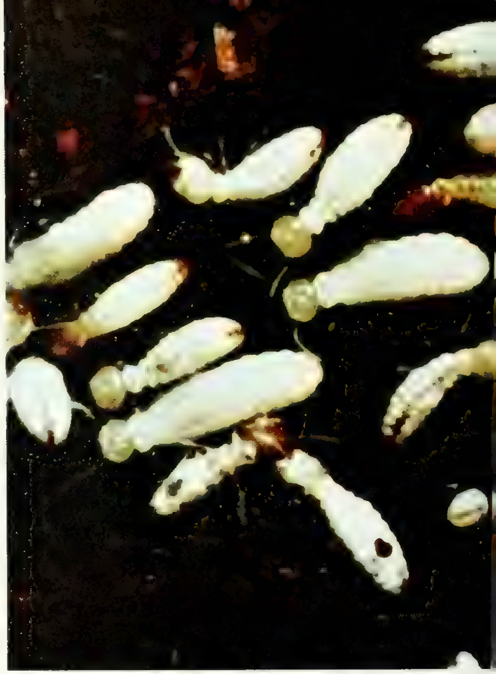
Damage to wood usually cannot be observed unless the exterior is stripped away. When it is, a series of galleries that give the wood a honeycomb appearance is revealed. The inside of feeding galleries is covered with grayish specks of excrement and earth. Infested softwoods appear honeycombed because termites feed on the softer wood a tree produces in spring and avoid the denser wood grown in summer.

Wood attacked by subterranean termites often appears honeycombed.



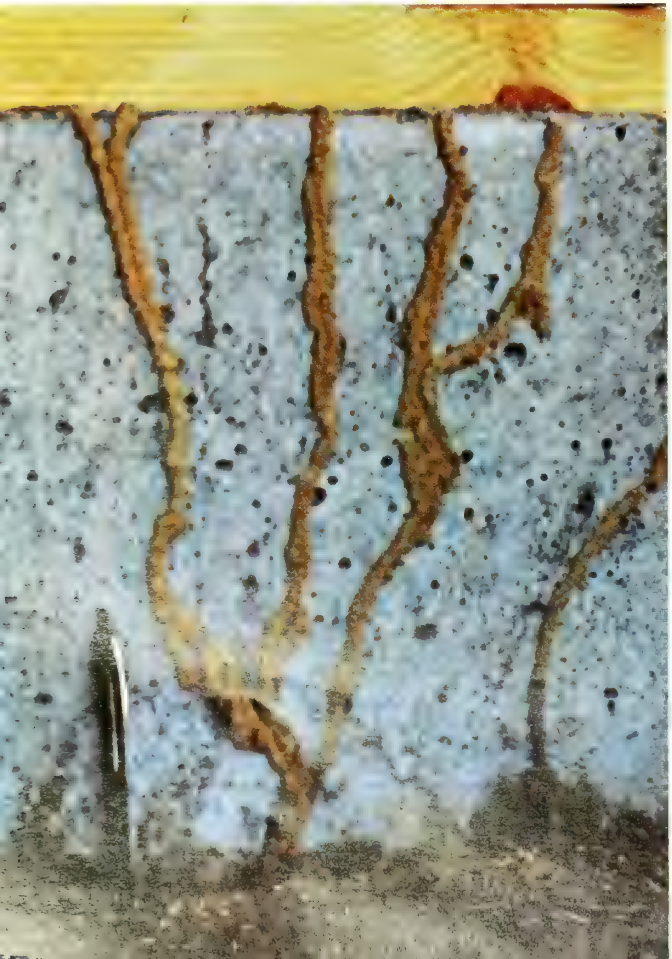
Workers may usually be seen when a piece of infested wood is examined. Both workers and soldiers are wingless and grayish white. Workers destroy wood, while soldiers guard the colony. The two forms are similar in size, but soldiers have much larger heads and longer mandibles or jaws.

Termite tubes are another sure sign that the insects have been at work. Subterranean termites often build these structures to enter a house from the soil. The tubes, about ¼ to ½ inch wide, provide passageways between the wood of the house and the soil from which the termites obtain moisture.



Subterr

Termite shelter tubes usually mean trouble.



Prevention and Control

The only practical way to prevent subterranean termite attacks or to rid a house of the insects is to deny them a source of moisture. Without moisture, a colony in a house will die. Thus, many of the tips for keeping wood dry to prevent decay are equally applicable for termite prevention.

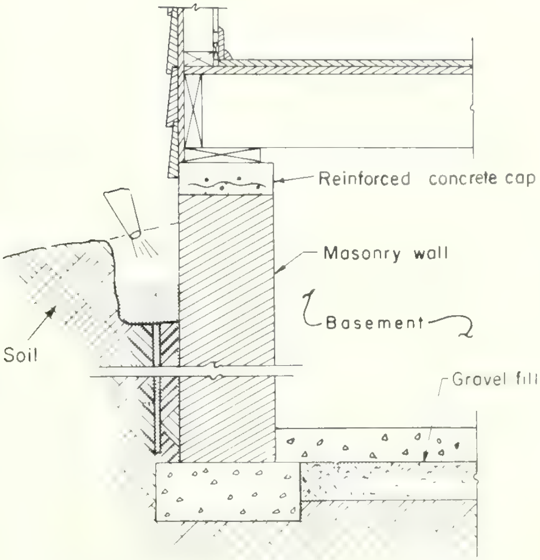
It should be remembered, however, that termites can attack dry wood by transporting moisture from the soil. How can the soil be eliminated as a moisture source?

Chemical barriers. Subterranean termites cannot maintain a connection between the soil and the wood in a house if the soil around and under the foundation is properly treated with an appropriate insecticide. Several insecticides

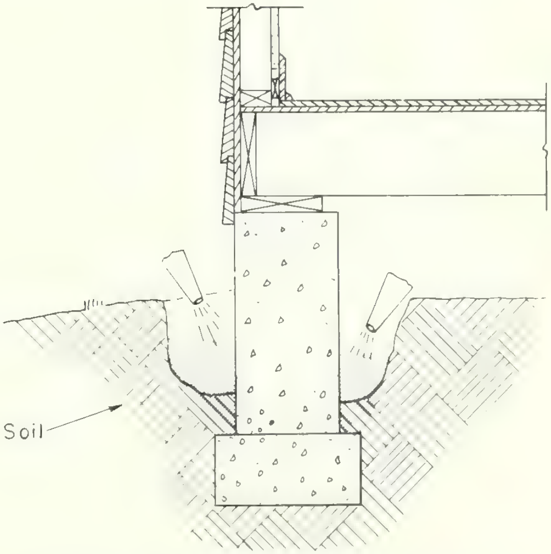
ith queen at center.

have proved highly effective for this purpose. In tests near Gulfport, Mississippi, where termite activity is very high, sufficient quantities of these chemicals applied to the soil have protected wood in contact with the soil for more than 20 years. The effectiveness of these insecticides in building protection depends upon the type of construction and the throughness of application.

The most practical time for applying insecticides is during construction of the house or any addition to the house. Then, the soil can be treated before concrete is poured. Once the house is built, it can be very difficult and expensive to get insecticide under the concrete in a slab or basement floor. Application during construction, or pretreatment as it is called, is required by many building codes.



Soil around walls and under floors of basements should be treated with insecticide.

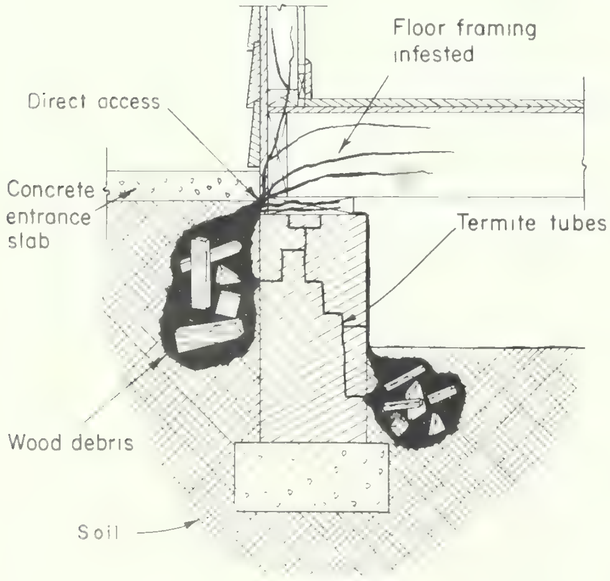


Soil along inside and outside of foundation walls should be treated with insecticide.

Termite Hazards

Certain construction features favor termite attack. A buyer should be aware of these features when he is inspecting a prospective home. An owner should understand the risks he is taking if he does not correct such features.

Earth-wood contacts.—Unless it has been pressure treated with a preservative, wood should never be placed in contact with the soil. Yet such contacts are common in many homes. Wooden steps, trellises, fences, lattice work, and framing around crawl space access doors all may be connected to the house and ground. All are potential hazards. If the wood must touch the ground it should be pressure treated with preservative. The soil where the wood is touching should be treated with insecticide. Piers and steps should be placed on a concrete support at least 4 inches above ground level.



Subterranean termites usually enter a house from the surrounding soil, either by tubing over foundation walls or by attacking wood in contact with soil.

Wood debris.—Removing wood debris and providing good drainage reduce the termite population close to houses. Wood debris adjacent to wood in the house can compromise the house's chemical defenses. All wood, including stumps and dead roots, should be removed from the building site before construction. Form boards and loose scraps of lumber should be removed before fill is placed around the new foundation. Underneath existing homes all loose wood should be raked out and removed. Stumps and large roots may be treated with insecticide rather than removed if they are not very close to foundation timbers.

Earthfill.—Earthfilled porches are a common entry area for termites. They should be constructed as described under DECAY, and the fill in them should be treated with insecticides. In existing porches, treatment often requires drilling through a concrete wall and resealing. Earthfills for carports, patio slabs, terraces, walkways, and the like should be treated at the junction with the house foundation.

Additions.—To expand their house, many owners enclose their former carports. Ordinarily, the soil beneath a carport is not thoroughly treated with insecticide. If an addition is planned, the entire soil area beneath the carport or slab addition should be treated.

Foundation wall voids exist in many homes and are a possible termite entryway. Proper control includes treatment of the voids in bricks or blocks.

Planting soil.—Homeowners often place soil against walls to plant flowers and shrubs. Unless this soil is treated with insecticide, it can provide an entryway for termites.

Termite shields.—Since termite shields are rarely properly installed and maintained, they give the homeowner a false sense of security. Shields are well-suited for capping masonry piers, and do give a house with a crawl space considerable protection. Properly installed, they can deter attack and force termites to tube over them into the open where attack can be observed. Shields on interior parts of piers or walls should extend 2 inches outward and 2 inches downward at a 45° angle. For appearance sake, a smaller extension is acceptable on exterior portions. Here, the 2 inches bent downward 45° are generally regarded as sufficient. There must be no cracks in the metal, and the shields must be 12 inches above ground.

Frequent Inspection

Since even the most prudent homeowner has no way of knowing how thoroughly the soil around and under his house has been treated with insecticide, frequent properly conducted inspections for evidence of termite attacks are excellent insurance. In the South and Pacific Coast States inspections should be made once a year. Look primarily for shelter tubes on piers and foundation walls, but also look for leaks that cause wood to become wet.

If discarded wings, shelter tubes, or other evidence of termite attack are found, do not be scared into hasty decisions. Well-established methods of control and expert assistance are available.

Seek Professional Help

Since control of subterranean termites requires application of insecticides that can be hazardous, it is often best to hire a professional pest control operator. This booklet gives only general information about treatment. Before attempting to control termites himself, a homeowner should read detailed instructions in "Subterranean Termites, Their Prevention and Control in Buildings," USDA Home and Garden Bulletin 64.

To avoid worry, many homeowners in areas of high termite hazard contract with a pest control company for control of subterranean termites. The company typically inspects the house and does whatever treating it deems necessary at a price that depends upon the amount of work. Thereafter, the company usually inspects annually for a fixed price. The company usually guarantees its work by repairing free any damage caused by subterranean termites.

In areas where the termite threat is great, the home buyer should ask whether the house he is looking over is covered by a pest control contract. These contracts usually are not transferable to the new owner, but their existance is a good indication that proper control measures have been taken.

A termite inspection is required before an FHA or VA loan can be obtained, and in many instances these inspections are thorough. The buyer can reassure himself, however, by arranging for an inspection by a pest control expert of his choice. It is a good idea to make certain that at least one such inspection is made because damage by other structural pests is often overlooked or ignored.

DRYWOOD TERMITES

Drywood termites cause serious damage in the Deep South, in southern Texas, New Mexico, and Arizona, and along the Pacific Coast in California. Damage by these insects can be recognized by the presence of **large, clean cavities** cut across the grain of comparatively **dry wood.** These cavities contain slightly compressed pellets of partially digested wood. Some of the pellets may be pushed through tiny openings in the wood surface. **Piles of pellets** below damaged wood are often the first signs of infestation. Drywood termite entrance holes are difficult to detect because they are sealed with a brownish-black, paper-thin secretion, which may contain pellets.

Drywood termites usually damage wood more slowly than subterranean termites. Thus, structural weakening by them is most likely to occur in old buildings.

Since drywood termites do not have ground connections, they must be killed by applying insecticide to galleries in the wood they are attacking. To reach the galleries, holes must be bored into the wood. After insecticide is injected, the holes should be sealed. In some instances, insecticidal dusts may be preferable to liquids. Dusts adhere to the bodies of the termites and may be spread from gallery to gallery until the entire colony is destroyed. Very severe infestations may require fumigation if the areas under attack are inaccessible. This is a job for a pest control operator.

WOOD-DESTROYING BEETLES

Beetles in three families cause extensive damage to the wood in buildings. *Lyctus* or powder-post beetles attack recently seasoned hardwood sapwood, and thus are usually found in new homes. Anobiid beetles feed on both hardwoods and softwoods and are usually associated with buildings older than 10 years. Old house borers only attack softwoods, primarily framing lumber. They prefer recently seasoned wood and most often occur in homes less than 10 years old. Damage by these beetles may occur anywhere in the United States, but the most severe attacks occur in warm, humid climates.

Fumigation is too expensive to justify unless an infestation of drywood termites or beetles is large, active, and inaccessible.

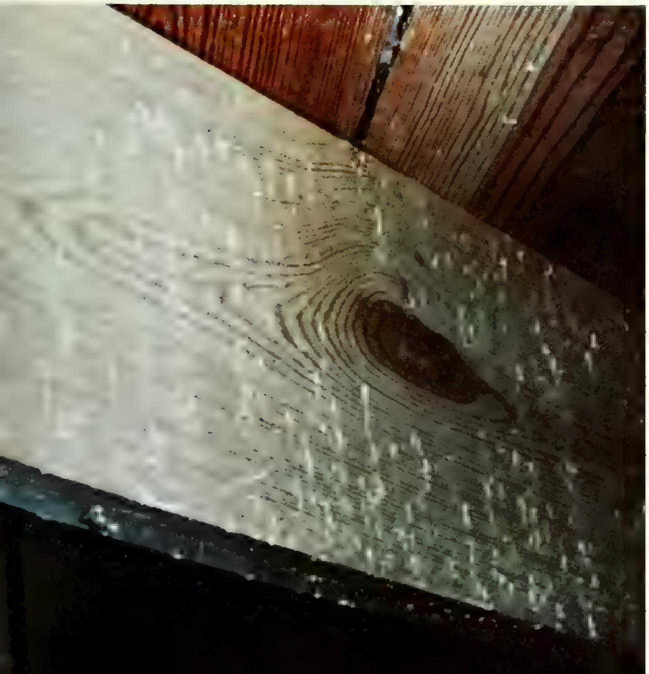
The damage is done by **larvae** or grubs, which tunnel in the wood for months or years before emerging as adult beetles. Since the larvae never come to the surface, their tunneling may be extensive before it is noticed.

All species must have **bare wood** on which to lay their eggs. Hardwood items in the home are usually finished with varnish, shellac, sealer, or wax, any one of which will prevent egg laying if no bare wood is exposed. Most lumber today is kiln-dried, and the heat of this process destroys eggs, larvae, and pupae. Sometimes, however, the lumber becomes infested during storage. That explains the emergence of beetles from wood during the first 5-10 years after a house is constructed.

The exposed, **unfinished wood in crawl spaces** is open to attack as long as a building stands. Keeping the crawl space dry through proper drainage and installation of a moisture barrier will minimize the risk. Crawl spaces and other places where bare wood is exposed should be inspected annually for evidence of attack.

Look for piles of **very fine sawdust** on or beneath wood, and for small **round** or **oval holes** in the wood surface. These holes are made by adult beetles when they emerge, usually during April through July. Since the commonest species are active mainly at night, no beetles will normally be seen during inspections.

Wood-destroying beetles (anobiids in this case) make small holes and leave powder on unfinished wood, especially in crawl spaces.

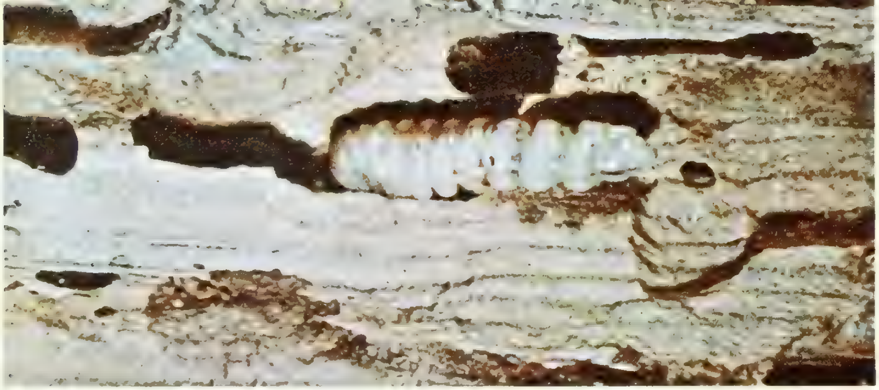


Attacks in unfinished wood can be expected to intensify until control measures are taken. Reinfestation is less likely in finished wood, but the beetles often lay eggs in their own exit holes.

When there are just a few exit holes in a piece of furniture, for example, insecticide can be injected into them. Small, easily accessible infestations in structural members of buildings can be sprayed or brushed with insecticides. If the pests have spread into the walls of the house, however, fumigation may be required. This work is dangerous, and should only be done by a professional.

Since fumigation is expensive the homeowner should assure himself that it is necessary before agreeing to it. He should make sure the infestation is **still active.** One way to do that is to clear all powder away from the suspected area. If new powder and holes appear, the insects are still active.

The homeowner should also make sure that the holes are being made by a species that will reinfest the wood after emergence. Damage by other insects is often mistaken for that of the wood-destroying beetles described. Ambrosia beetles, for example, attack dead and dying trees and logs in the woods, making small holes which often have **stain** around them. When a crawl space or other area is being inspected for troublesome damage, the homeowner may find wood with holes in it made by ambrosia beetles. These holes were made before the wood was

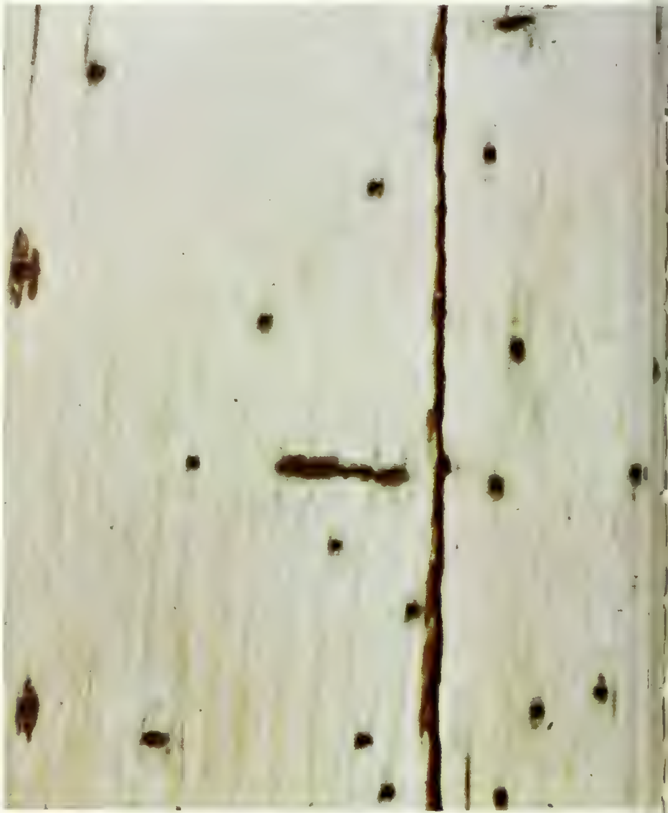


Larvae, not adult beetles, feed on wood. Larvae of old house borers make oval holes up to 1/4 inch in diameter.

sawn. These beetles do not reinfest dry wood so the damage will not increase. Ambrosia beetle holes contain **no powder**, while the tunnels of beetles that attack dry wood always contain powder. Holes of the latter usually come straight out of the wood, but the angle of ambrosia beetle holes is often far different from 90 degrees.

Various wood borers attack dying trees or logs in much the same way that old house borers attack wood in buildings. These other borers, however, do not reinfest the wood in houses once they have left it. Such insect holes may appear during the first 5 years after a home is built. The damage will not get worse. The best way of distinguishing the relatively unimportant damage of these borers from the very serious damage of the old house borer is by looking at the powder around the exit holes. Old house borers produce a **fine, tightly-packed powder.** Other borers produce loose, fibrous shavings.

Bark beetles feed upon the inner bark of trees. Rough-sawn framing lumber often has small pieces of bark on it. Shallow **holes in and around bark** were made in the woods. They are no cause for worry.



Holes of ambrosia beetles are made before wood is sawn. Damage will not get worse. Note stain around holes.

WOOD-NESTING INSECTS

Unlike other insects mentioned here, carpenter ants and carpenter bees do not eat wood. They simply nest in it. This concept is of small comfort to the owner of a home that is infested, however. These insects cause considerable damage in making their nests, and are a major nuisance around the house.

Carpenter ants are easy to recognize; they are large and reddish-brown to black. Workers are from ¼ to ½ inch long. Indoors these ants feed on sweets and other foodstuffs. The workers have strong jaws and will bite when disturbed.

Colonies are started by mated queens, which seek damp wood for a nest. Once it is established, however, the nest will be expanded into dry, sound wood. The ants carve out galleries for living quarters, and they keep the galleries clean and smooth. Excavated sawdust is dumped outside the nest.

While the presence of large ants around the house is usually the first sign of an infestation, it does not necessarily mean that the nest is inside the house. The nest may be in a stump or hollow tree adjacent to the house.

The homeowner needn't be told to kill all the ants he sees; he will do that on his own. Frequent spraying of insecticide on areas where ants are seen sometimes eliminates a colony. Since this is a slow process and may not be effective, however, great effort should be made to locate the nest. Insecticide applied to it will eliminate the colony.

Wood that may have become damp should be inspected. Objects that are often attacked include porch pillars and supporting timbers, sills, girders, joists, studs, and window and door trim. It is a good idea to probe suspected wood with a sharp object. If the wood gives way under probing and ants come tumbling out, the nest has probably been located.

Black carpenter ant.

Carpenter bees, which look a lot like bumblebees, occasionally nest in the wood in buildings in many parts of the United States. They can be recognized by their bare, shiny abdomens. The abdomens of bumblebees are covered with rows of dense, yellow hair.

Relatively soft wood is preferred for nesting, and unpainted, well-weathered wood is far more likely to be attacked than wood on which a paint film has been maintained. Typical nesting sites on houses include porch ceilings, windowsills, doorframes, headers, siding, and other places that are somewhat sheltered.

The bees cut an entrance hole about ⅝ inch in diameter across the grain of the wood, and construct galleries with the grain. The damage caused by one or two bees is usually slight, but if they are not controlled they can cause serious damage over a long period.

The only practical control method is to apply insecticide to the nest galleries. By observing the bees, their nests can usually be located without difficulty.

HEALTH CHECKLIST

If you are thinking of buying a house, you will want to assure yourself that it is healthy. The questions listed below will help you make a thorough inspection. Most are also applicable to a house you already own.

1. *Is all wood in the house above the level of the soil?*
2. *Does water drain away from house?*
3. *Does the crawl space have adequate clearance and ventilation? Is its soil covered with a moisture barrier?*
4. *Are there signs of dampness in the basement?*
5. *Are earthfilled porches and other structures separated from the house?*
6. *Is roof overhang sufficient?*
7. *Has caulking around windows, doors, and joints been maintained?*
8. *Are gutters and downspouts intact?*
9. *Is attic vented?*
10. *Is roof decking completely covered, especially at roof edge?*
11. *Does roof sag, indicating possible rafter decay?*
12. *Is paint peeling or blistering?*
13. *Are decorative and other items attached to the house likely to admit or trap moisture?*
14. *Is plumbing, including drains, free of leaks?*
15. *Do doors sag or windows stick? Are frames decayed?*
16. *Is caulking around tubs, sinks, and showers intact?*
17. *Are floors level? Do spots feel spongy when walked on?*
18. *Do ceilings have water damage?*
19. *If the house is in a zone of high termite hazard, is there a structural pest control contract on it? Does the contract include a guarantee?*
20. *Was the soil under the house treated with insecticide during construction? Afterward?*

21. *Has the soil under additions been treated?*

22. *Are any termite shelter tubes visible on foundation? On pipes?*

23. *Does the crawl space contain stumps or wood debris?*

24. *Are there small holes in unfinished wood in the crawl spaces or elsewhere with powder under them?*

25. *Will an expert inspect the house for termites or other structural pests before the sale?*

ADDITIONAL INFORMATION

County agents and university extension workers are excellent sources of up-to-date information on pest control. In addition, helpful publications of the U. S. Department of Agriculture are available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. Some of these publications and their prices are:

Controlling wood-destroying beetles in buildings and furniture. 1972. Williams, L. H., and Johnston, H. R. USDA Leaflet 558. 10 cents

Protecting log cabins, rustic work, and unseasoned wood from injurious insects in the Eastern United States. 1970. St. George, R. A. USDA Farmers' Bulletin 2104. 15 cents

Subterranean termites, their prevention and control in buildings. 1972. Johnston, H. R., Smith, V. K., and Beal, R. H. USDA Home and Garden Bulletin 64. 20 cents

Wood decay in houses: how to prevent and control it. 1972. USDA Home and Garden Bulletin 73. 15 cents

Another reference that may be helpful is "Principles of Protecting Wood Buildings From Decay" by T. C. Scheffer and A. F. Verrall, USDA Forest Service Research Paper FPL 190. Single copies are available free from the Forest Products Laboratory, P. O. Box 5130, Madison, Wisconsin 53705.

PRECAUTIONS

This booklet does not contain recommendations or specific instructions on the use of pesticides. Such chemicals often are needed to protect wood from insects and decay. Specific information on the proper chemicals and their use should be obtained before any attempt is made to apply them.

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Registrations of pesticides are under constant review by the Environmental Protection Agency. Use only pesticides that bear the EPA registration number and carry directions for home and garden use.

PROTECT

Use Pesticides Safely
FOLLOW THE LABEL
U.S. DEPARTMENT OF AGRICULTURE

U. S. Department of Agriculture
Forest Service General Technical Report SO-2

Pine Nutrition In the West Gulf Coastal Plain: A Status Report

Eugene Shoulders
and
W. H. McKee, Jr.

Southern Forest Experiment Station
Forest Service
U. S. Department of Agriculture

1973

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PINE NUTRITION IN THE WEST GULF COASTAL PLAIN: A STATUS REPORT

Eugene Shoulders and W. H. McKee, Jr. [1]

Review of current literature establishes that forest fertilization is a proven, accepted management practice in limited areas of the South where lack of one or more mineral nutrients seriously curtails pine growth and where moderate additions of these nutrients markedly increase yields. In most of the South, however, and especially in the West Gulf Coastal Plain, general use will be deferred until amounts, kinds, and schedules of application can be reliably specified for individual soils.

Additional keywords: Fertilization, nutrient cycling, soil fertility.

In recent years, forest landowners have become keenly interested in mineral nutrition of southern pines and especially in fertilizing them to stimulate growth. Many factors have contributed: among the most important are a diminishing land base on which to grow wood and fiber to supply an expanding population, research that shows economic returns from commercial fertilization of selected stands on problem soils, and adoption by many landowners of other intensive regeneration and management practices that make fertilization a logical next step.

Many questions must be answered before commercial fertilization of southern pines can be routinely recommended. This paper considers both soil and plant aspects of the problem. It summarizes current knowledge of the chemical properties that determine the ability of soils to hold added nutrients in forms available to pines. It also evaluates results of greenhouse and field studies which indicate the kinds and amounts of nutrients required for optimum or maximum growth. In addition, it considers the impacts of climate, of physiological condition of the trees, and of genetic variation within species on response of pines to added nutrients.

The discussion is concerned chiefly with pine growth on Coastal Plain soils of Arkansas, Louisiana, Mississippi, and Texas. Much of it, however, applies equally well to other parts of the South. For those who wish a broader view, the authors strongly recommend concurrent study of "Forest fertilization research in the South: a review and analysis" (Southern Forest Environment Research Council, 1972), which may be obtained from any State agricultural experiment station in the South.

CLIMATE, SOILS, AND VEGETATION

Climate of the region varies. The growing season is longer and winter temperatures are milder near the Gulf Coast than inland. The mean frost-free period ranges from 210 days in central Arkansas to 300 days near the Coast (Southern and Southeastern Forest Experiment Stations, 1969). Average normal January temperatures vary from 45°F in the north to 55° in the south. July temperatures average 82°F thoughout the region. Annual rainfall varies from about 40 inches near the western fringe of the east Texas pineries to 60 inches in southeast Mississippi. Winter rainfall is ordinarily adequate or excessive, but growing-season rainfall is erratic. By midsummer, moisture deficits often limit growth of crops (Van Bavel, 1959). Frequency and severity of these deficits intensify from southeast to northwest.

Soils which now support or are apt to be converted to pines in the foreseeable future can be divided into three broad groups: poorly and imperfectly drained flatwoods soils, well drained upland Coastal Plain soils, and soils derived from loessal deposits (Lytle, 1960). Each group contains several series that vary in physical properties and in their abilities to retain added nutrients in forms available to pines. Representative important series in each group are listed in table 1. Flatwoods soils predominate near the coast. Throughout much of the area, moreover, flatwoods and upland Coastal Plain soils are intermixed, with the former occurring on the lower, leveler portions of the landscape and the latter occupying the higher, more sloping relief. Loessal soils are confined to a narrow strip on either side of the Mississippi River and may occupy the entire landscape or only the ridge tops.

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[1] The authors are Principal Silviculturist and Principal Research Soil Scientist in the research unit on Intensive Culture of Southern Pines, Southern Forest Experiment Station, USDA Forest Service, Alexandria, Louisiana.

Soils of the flatwoods have poorly developed profiles. Typically, they are saturated with water through part or all of the winter and become reduced during this period (McKee, 1970; McKee and Shoulders, 1970). Surface and internal drainage are poor because of low topographical position and relatively impermeable subsoils. Parent material is of recent and late Pleistocene age (Lytle, 1960). Mineralogy is mixed but kaolinitic clays predominate.[2] Vermiculites are second in importance. Montmorillonite predominates in the B-horizon of the Acadia series. In general, surface soils of the West Gulf flatwoods tend to be more silty than their counterparts farther east.

Native vegetation in the flatwoods was predominantly longleaf (*Pinus palustris* Mill.) and slash (*P. elliottii* var. *elliottii* Engelm.) pine

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[2] Godfrey, C. L., Welch, C., and Coover, J. R. Texas correlations—soil type, soil fertility, soil salinity. Unpublished report, Tex. A&M Univ. 1964.

Table 1.—*Classification and drainage characteristics of some important pine growing soils of the West Gulf Coastal Plain*

Physiographic province and series	Sub-group	Family	Drainage
Flatwoods			
Caddo	Typic Glossaqualfs	Fine-silty, siliceous, thermic	Poorly
Guyton	Typic Glossaqualfs	Fine-silty, siliceous, thermic	Poorly
Wrightsville	Typic Glossaqualfs	Fine, mixed, thermic	Poorly
Acadia	Aeric Ochraqualfs	Fine, montmorillonitic, thermic	Somewhat poorly
Bude	Glossaquic Fragiudalfs	Fine-silty, mixed, thermic	Somewhat poorly
Bibb	Typic Fluvaquents	Coarse-loamy, siliceous, acid, thermic	Poorly
Iuka	Aquic Udifluvents	Coarse-loamy, siliceous, acid, thermic	Moderately well
Leaf	Typic Albaquults	Clayey, mixed, thermic	Poorly
Myatt	Typic Ochraquults	Fine-loamy, siliceous, thermic	Poorly
Rains	Typic Paleaquults	Fine-loamy, siliceous, thermic	Poorly
Beauregard	Plinthaquic Paleudults	Fine-silty, siliceous, thermic	Moderately well
Upland Coastal Plain			
Boswell	Vertic Paleudalfs	Fine, mixed, thermic	Moderately well
Susquehanna	Vertic Paleudalfs	Fine, montmorillonitic, thermic	Somewhat poorly
Kirvin	Typic Hapludults	Clayey, mixed, thermic	Well
Luverne	Typic Hapludults	Clayey, mixed, thermic	Well
Ruston	Typic Paleudults	Fine-loamy, siliceous, thermic	Well
Shubuta	Typic Paleudults	Clayey, mixed, thermic	Well
Sawyer	Aquic Paleudults	Fine-silty over clayey, siliceous, thermic	Moderately well
Lucy	Arenic Paleudults	Loamy, siliceous, thermic	Well
Stough	Fragiaquic Paleudults	Coarse-loamy, siliceous, thermic	Somewhat poorly
Bowie	Fragic Paleudults	Fine-loamy, siliceous, thermic	Moderately to well
Troup	Grossarenic Paleudults	Loamy, siliceous, thermic	Well
Eustis	Psammentic Paleudults	Sandy, siliceous, thermic	Somewhat excessively
Loessal Deposits			
Henry	Typic Fragiaqualfs	Coarse-silty, mixed, thermic	Poorly
Calhoun	Typic Glossaqualfs	Fine-silty, mixed, thermic	Somewhat poorly
Loring	Typic Fragiudalfs	Fine-silty, mixed, thermic	Moderately well
Providence	Typic Fragiudalfs	Fine-silty, mixed, thermic	Moderately well
Olivier	Aquic Fragiudalfs	Fine-silty, mixed, thermic	Moderately well
Grenada	Glossic Fragiudalfs	Fine-silty, mixed, thermic	Moderately well
Memphis	Typic Hapludalfs	Fine-silty, mixed, thermic	Well

with an understory of scrub oaks *(Quercus* spp.), southern bayberry *(Myrica cerifera* L.), and native grasses (principally *Andropogon* spp. and *Muhlenbergia expansa* [D.C.] Trin.). Loblolly pine *(P. taeda* L.) was also present in varying degrees. Slash pine is preferred in planting, except that loblolly is used in the north part of the region and on some of the less poorly drained flatwoods elsewhere.

By agronomic standards, fertility is consistently low and may vary cyclically with winter saturation and summer drying (McKee, 1970).

Soils of the upland Coastal Plain are moderately to excessively drained and their profiles are better developed than those of the flatwoods. They are derived from marine or stream alluvium of Eocene to Pleistocene age (Lytle, 1960; Carson and Kunze, 1967). Their mineralogy is mixed; however, a comprehensive regional analysis of the clay fraction is not available. Profiles from Texas indicate that the clays are predominantly kaolinitic with some vermiculite.[2] Exceptions are the soils of the Susquehanna and Boswell series, which are high in montmorillonite.

The surface soils appear to have less organic matter than those of the flatwoods, probably because better aeration promotes decomposition of organic debris. Textures range from very fine sandy loam to sand. Subsoils vary but the B horizons usually are finer textured and less permeable than the surface layers.

Native vegetation consisted of longleaf, loblolly, and shortleaf *(P. echinata* Mill.) pine, often mixed with hardwoods. Loblolly pine is the predominant species in recent plantations and managed natural stands.

Data from Louisiana on nutrients available for agronomic crops indicate that upland Coastal Plain soils are acid and low in nitrogen, phosphorus, and potassium (Brupbacher et al., 1970). The resemblance between upland and flatwoods soils in these properties does not assure that the two can be grouped in the study of pine nutrition, especially if drainage affects response to fertilizers in the West Gulf Region as it did in Florida. There, phosphorus increased pine growth more often on poorly drained than on well drained soils, even though levels of extractable nutrients were comparable (Pritchett and Llewellyn, 1966; Pritchett and Smith, 1972). Better-drained soils do not undergo waterlogging in winter. Their acidity and ability to keep available nutrients in the rooting zone may vary seasonally, however, as amounts of precipitation and degree of soil saturation influence aluminum dissociation and microbial activity (Coleman and Thomas, 1967).

Parent materials of soils derived from loess are of late Pleistocene age (Lytle, 1960). These soils occur on flat to rolling or hilly terrain and generally have moderate surface runoff and internal drainage. Some, however, have fragipans that perch water tables during wet seasons.

The mineralogy is a mixture of illite, montmorillonite, vermiculite, and kaolinite (Antie et al., 1970). The less weathered clays tend to give these soils higher permanent exchange capacities than the upland Coastal Plain or flatwoods soils and greater potentials for crops to respond to fertilizer. Nevertheless, soils derived from loess are usually infertile. They are inherently acid.

Native vegetation consisted of mixed hardwood and pine-hardwood forests. Because of their capacity to hold nutrients and their desirable physical properties, many of the soils derived from loess are now in cropland or improved pasture. The trend toward nonforest use is apt to continue, except where permanent cover is required to prevent erosion of moderate to steep slopes. The special problems in management of loessal soils on such landscapes are beyond the scope of this review. Both loblolly and slash pine are grown; slash is preferred in the southern and loblolly in the northern part of the region.

NUTRIENT-HOLDING PROPERTIES OF SOILS

Cations

Almost all important pine-growing soils of the region are characterized by low exchange capacities with weak charges that are highly pH-dependent (Coleman and Thomas, 1967). The variable, or pH-dependent, charge originates mostly from organic matter, exchangeable aluminum, and amorphous oxides. The individual and collective contributions of these components to cation retention characteristics of individual soils, and the abilities of individual soils to hold nutrient cations in forms available to pines, must be determined before fertilizer prescriptions developed for one soil can be confidently extended to another.

Some study of methods for determining cation exchange capacity (CEC) is also needed. Methods ordinarily used sometimes give values —for both imperfectly and well drained Coastal Plain soils—which are lower than the level of exchangeable bases the soils contain. What is known of the exchange properties of the various components of the complex is summarized below.

Clay minerals represent the most stable portion of the exchange complex, and the one least likely to be affected by the environment or fertilizers. As indicated above, kaolinites are probably the predominant clay minerals in most flatwoods and upland Coastal Plain soils. Kaolinite normally has a weak charge and an exchange capacity of about 10 milliequivalents per 100 grams of clay. Since clay comprises no more than 10 to 20 percent of the topsoil of many series (U.S. Soil Conservation Service, 1966), not more than one-fourth to one-third of the total exchange capacity of such topsoil may be attributed to it. The remainder is associated with organic matter, exchangeable aluminum, and amorphous oxides.

Retention and exchange of individual cations by kaolinitic clays depend on the ion species involved and the level of other cations (Wiklander, 1964). Moreover, there is a direct relationship between soil pH and the proportion of the total CEC that is occupied by bases, i.e., base saturation (Mehlich, 1942). Generally, nutrient exchange between kaolinite and plant roots is optimized by a base saturation of 40 to 50 percent (Marshall, 1964), which occurs above pH 6 (Mehlich, 1942). Since southern pines seem to prefer more acid soil, a base saturation of 30 percent may be better for them.

With base saturations from 30 to 50 percent, potassium is found in much greater amounts in the solution phase than on the exchange sites of kaolinitic systems. Consequently, only a small amount is fixed on the exchange sites to resupply the solution phase (Hipp and Thomas, 1967). Moreover, most of the potassium added in fertilizers must be taken up rapidly by plants or be lost to ground water. The divalent cations Ca ++ and Mg ++ are held more tightly by the mineral fraction of the soil than are monovalent cations such as potassium (K+). In consequence, smaller amounts of divalent ions are in solution and plants have to compete more with the clay for calcium and magnesium than for potassium. Availability of the calcium and magnesium over the ranges of base saturation found in this region probably can be described by the ratio law (Marshall, 1964).

The CEC of soil organic matter is quite variable but averages about 100 milliequivalents per 100 grams of material (Coleman and Thomas, 1967). The charge is highly pH-dependent, with about 40 milliequivalents per 100 grams' increase in CEC for each unit increase in pH (Wells and Davey, 1966; Khan 1969). Organic matter is normally much lower and should be expected to contribute less to the exchange capacity in well drained than in poorly drained soils. However, since organic matter of better drained soils may have more active sites per unit weight of material, the decrease in percent of organic matter does not necessarily mean a decrease in its total acid activity in the soil (Ponomareva and Plotnikova, 1957).

Organic matter tends to hold monovalent cations less strongly and multivalent cations more strongly than do clay minerals (Coleman and Thomas, 1967). Moreover, because organic matter complexes with multivalent metallic ions, different ion species do not replace each other on organic exchanges in readily predictable patterns (Evans, 1968; Naylor and Overstreet, 1969; Marshall, 1964). At low pH, multivalent cations may prevent potassium from occupying organic exchange sites (McLean and Owen, 1969).

The exchange capacity due to exchangeable aluminum and other amorphous material is also weak; however, dissociation of amorphous material is less influenced by pH than is dissociation of organic matter, and the affinity of exposed sites to individual cations is different (Coleman and Thomas, 1967). The force by which cations are bound to exchange sites of amorphous material depends on the ionic strength of the site and the cation as well as the valence of the ion (Helling et al., 1964). In this respect, amorphous oxides and exchangeable aluminum behave more like clay minerals than like organic matter (Marshall, 1964). Their variable charge is reported to arise from the dissociation of hydrogen from hydroxy groups (De Villiers and Jackson, 1967).

At low pH's, amorphous materials have two other distinctive properties that may be important in fertilization of forest soils of the region: (1) amorphous oxides act as salt exchangers, holding both cations and anions on the exchange sites (Thomas, 1960); and (2) exchangeable aluminum complexes ammonia (Hunsaker and Pratt, 1970).

The contribution of amorphous material to the total charge may vary somewhat between flatwoods and upland Coastal Plain soils. On flatwoods soils, waterlogging in winter is thought to increase pH by reducing amorphous iron compounds to the soluble ferrous form (McKee, 1970). The reaction may precipitate aluminum in an inactive form. This hypothesis is supported by the fact that aluminum phosphates decrease and iron phosphates increase under waterlogging. Levels of exchangeable macronutrients are also depressed, probably because they are replaced by reduced iron and manganese on the exchange complex. These reactions appear to be slowly reversible and hence to result in a seasonal cycling in nutrient status of flatwoods soils. The effects of waterlogging need definitive study.

The effective CEC of a soil may be considerably less than the sum of charges on individual components of the complex. This masking of charge has been attributed to formation of amorphous-organic matter complexes (Marshall, 1964) and of iron oxide coating on clay micelles (Roth, 1969). In Roth's research removal of iron oxide coatings increased the non-pH-dependent charge of clay by 10 to 60 percent. A reaction of this type may accompany reduction of poorly drained flatwoods soils; however, the reoxidation of iron should reestablish the amorphous coatings. Some evidence has been accumulated that coatings are influencing the effective CEC of flatwoods soils.[3]

Moisture may also influence the acid reactions of weakly charged, amorphous oxides on upland soils (Westfall, 1968). Drying tends to cause greater dissociation of aluminum hydroxide and to decrease pH. As a result, pH on many soils of the region may be 0.5 to 1.0 lower in fall than in winter.

Higher levels of exchangeable bases are also found in these soils in late summer. Factors contributing to the increase are incompletely understood, but among them are a faster release of cations from organic debris in summer than in winter, and the exposure of additional exchange sites through dissociation of amorphous hydroxides. No information could be found relating seasonal patterns of soil acid properties to pine nutrition.

Phosphorus

In addition to occupying exchange sites on soil colloids, calcium, iron, and aluminum react with phosphorus to form a variety of compounds, each of which reacts differently to changes in pH (Huffman, 1962). The reactions profoundly influence retention and distribution of applied phosphorus in the rooting zone and its availability to plants.

Fox and Kamprath (1971) found, for example, that soluble monocalcium phosphate fertilizer leached rapidly through an acid organic soil devoid of aluminum oxides and exchangeable aluminum. Addition of exchangeable aluminum almost completely immobilized phosphorus, because it reacted with the aluminum to form relatively insoluble compounds. White and Pritchett (1970) reported that phosphorus moved rapidly through the profile of poorly drained sandy soils in Florida. In a more detailed study of several Florida soils, Humphreys and Pritchett (1971) found that retention of superphosphate fertilizer was related to phosphorus sorption and buffering capacities. Seven to eleven years after application, the added phosphorus had disappeared from the surface 8 inches of soils apparently lacking in these attributes. Most of it remained in this layer of soils having detectable capacities to sorb or buffer solution phosphorus. The predominant fraction in which soil phosphorus occurred was observed to shift from aluminum to iron as sorption and buffering capacities increased.

Almost nothing is known of the movement of phosphorus in pine soils of the West Gulf.

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[3] Personal communication with Drs. M. S. Bhangoo and D. J. Albritton, Univ. of Arkansas at Pine Bluff, Ark.

Before closed stands can be fertilized with confidence, research is needed to learn which soils will retain added phosphorus at the surface, out of reach of feeder roots, and which soils will not unduly restrict movement of phosphorus into the root feeding zone. On soils where downward movement is seriously curtailed, ways must be found to place phosphorus where it can be utilized efficiently by pines, without injuring roots unduly, reducing growth, or promoting root disease.

Huffman (1962) stated that the rate of dissociation of aluminum and iron phosphates increases with pH over the range 3 to 11, whereas the rate of calcium phosphate dissociation declines over the same range. His phase diagram indicates that more phosphorus will be in solution and available to plants at pH 5.5 to 6.0 than at higher or lower pH's. This interpretation assumes that the phosphorus reactions are not limited by the amount of aluminum, calcium, or iron present—i.e., that there are sufficient quantities of all elements to establish stable equilibrium between the various compounds.

The amount of soil phosphorus in the aluminum, calcium, and iron fractions can be estimated (Chang and Jackson, 1957), and the phosphorus fractions were used successfully to show the availability of this nutrient to corn and soybeans on a variety of soils in Mississippi (Singh, 1970). The aluminum fraction accounted for most of the phosphorus uptake on acid soils and the calcium fraction for most on alkaline soils. Similar definitive research has not been done for southern pines, but McKee's (1973) data strongly suggest that slash pine seedlings derive most of their phosphorus from the calcium and aluminum fractions.

The approach of estimating phosphorus availability by identifying phosphorus compounds and determining their solubility products has not been universally accepted. Lewis and Quirk (1967) believed an intensity factor is also required; they expressed the factor as the ratio of phosphorus in solution to total mineral phosphorus in the soil. White and Haydock (1967) found that the intensity factor of a variety of Australian soils could be characterized by $NaHCO_3$ extraction of phosphorus with pH buffered to 8.5. The method worked well on all but the very acid soils.

On phosphorus-deficient soils in New Zealand, Ballard (1971) found good agreement between site productivity for *P. radiata* D. Don and the amount of soil phosphorus that was extracted with $NaHCO_3$—a method described by Olsen et al. (1954). Since the relationship was improved by considering the percentage of fine sand in the surface 4 inches, Ballard concluded that the Olsen test did not completely reflect availability over the range of soils he studied.

Alban (1972) found closer correlation between red pine (*P. resinosa* Ait.) site index in Minnesota and soil phosphorus if extraction was with H_2O, 0.002 N H_2SO_4, or 0.01 N HC1 than if stronger reagents were used. He included in the stronger reagents 0.5 N $NaHCO_3$ (Olsen et al., 1954), 0.025 N HC1 + 0.03 N NH_4F (Bray and Kurtz, 1945; Method 1), 0.10 N HC1 + 0.03N NH_4F (Bray and Kurtz, 1945; Method 2), 0.04 N HC1 + 0.025 H_2SO_4 (Nelson et al., 1953), and 0.4 N HC1.

In the South, the State of Florida has recommended extraction with acid ammonium acetate to estimate the amount of soil phosphorus available to pines (Pritchett and Llewellyn, 1966), while Virginia and North Carolina have used Nelson et al.'s (1953) mixture of sulfuric and hydrochloric acids for routine extractions.

It is uncertain if any of these approaches will be completely satisfactory in the West Gulf Coastal Plain. Selection of extraction solutions requires knowledge of local mineralogy, the phosphorus carrier, and the correlation between amounts of nutrient extracted and plant growth. Only recently has research been undertaken to compile such information for pines on West Gulf Region soils.

The cyclic reduction and oxidation that accompanies waterlogging and drying of flatwoods soils alters soil pH and causes large shifts in the proportions of phosphorus in the aluminum and iron fractions. When these soils are kept well aerated, added phosphorus seems to be divided among fractions in the same proportions as native phosphorus (McKee, 1970). The reactions increase the difficulty of devising methods for estimating levels of phosphorus available to pines growing on particular soils.

Nitrogen

Retention of nitrogen in forest soils is so intimately associated with nutrient cycling that separate consideration is impractical. It should be noted here, however, that ammonium nitrogen behaves very much like other monovalent cations in exchange reactions and that nitrate nitrogen quickly leaches from the profile if it is not taken up by soil microorganisms or by higher plants (Nommik and Popovic, 1971).

NUTRIENT CYCLING IN EVEN-AGED SOUTHERN PINE STANDS

Mineral nutrition, and especially nitrogen nutrition, of southern pines is closely tied to the cycling of elements in the ecosystem. A thorough understanding of this dynamic process is prerequisite to any research in commercial fertilization.

Knowledge of the nitrogen cycle in even-aged stands of southern pines is fragmentary. Information is available, however, to depict the range of nitrogen contents in the aboveground portions of managed stands to about age 30.

Smith (1965) observed that a 5-year-old loblolly pine plantation on a bottom-land site in Mississippi contained 64 pounds of nitrogen per acre in boles, branches, and foliage. This was an increase of 30 pounds over the amount present 1 year earlier. Comparable data for another plantation showed that 10-year-old trees had accumulated 140 pounds of nitrogen per acre aboveground. White and Pritchett (1970) found varying amounts in the biomass of a 5-year-old plantation of loblolly and slash pines in Florida; the quantity depended on depth to the water table and fertilizer treatment. Under the most favorable water regime, unfertilized loblolly contained 96 pounds per acre of nitrogen in the aboveground portions. Slash pines under the same conditions contained 168 pounds in their entire biomass (including roots). Fertilization with 350 pounds per acre of diammonium phosphate (18-46-0) increased nitrogen content by 27 percent for loblolly and 47 percent for slash pine. Working on Piedmont soils with a site index of 85 feet, Ralston and Prince (1965) estimated that about 175 pounds per acre of nitrogen was held aboveground by a 30-year-old loblolly pine stand containing 100 square feet of basal area per acre.

With allowance for a variety of soils and age classes, wide geographic distribution of the stands, and species differences in uptake of nutrients, these several estimates of nitrogen content of the aboveground biomass agree reasonably well.

Amount of nitrogen annually returned to the soil has been variously estimated. Smith (1965) thought that about 60 pounds per acre were recycled in a 4-year-old loblolly stand. Switzer et al. (1968) reported an annual return through litter fall of 27 pounds per acre for a 20-year-old loblolly pine plantation on an abandoned field in central Mississippi. At this age, uptake by the aerial portion of the trees was exceeding return to the soil by only 7 pounds per acre annually, and the quantity of cycling within the system was about 9 times that being immobilized. Maximum rates of uptake appeared to occur during the first 10 years of the stands' life.

In an earlier paper, Switzer et al. (1966) reported that loblolly pine stands during their first 30 years accumulated nitrogen aboveground at a mean annual rate of 6.3 pounds per acre on good sites and 5.0 pounds on poor sites. Annual accumulation during the next 30 years averaged 1.4 and 1.5 pounds per acre. Thus, about ¾ of the total was accumulated during the first 30 years.

The model developed by Switzer et al. (1968) showed that soils under 20-year-old loblolly pine ecosystems on good sites contained about 1,700 pounds of total nitrogen per acre but were supplying only about 34 pounds annually to the trees. The reason for this poor recovery rate may be that most of the soil nitrogen is immobile, or nearly so. Jorgensen (1967) found that less than 10 percent of the total nitrogen in three North Carolina Piedmont soils was in readily available forms (i.e., NO_3^- and exchangeable NH_4^+). The remainder was tied up in various organic compounds; over 50 percent of the total was in amino acids and 22 percent was in amino sugars.

The rate at which organic nitrogen is mineralized or made available to pines in other forms has not been reported for forest soils of the West Gulf, nor has the rate of addition of nitrogen to the soil through rain and nitrogen-fixing organisms. The impact of other nutrients and tillage on nitrogen cycling also has been inadequately researched.

Abundance of nutrients in the tree biomass (aboveground or total) of southern pine stands appears to be in the order $\mathrm{N} > \mathrm{Ca} \lessgtr \mathrm{K} > \mathrm{Mg} > \mathrm{P}$. Switzer et al. (1968) reported that loblolly pine stands under 30 years of age contained more potassium than calcium in their aboveground biomass but that the trend reversed with time because of greater immobilization of calcium in woody parts. White and Pritchett's (1970) data, however, show a greater accumulation of calcium than potassium in aboveground parts of a 5-year-old loblolly plantation in Florida. Potassium is highly mobile, and much of it appears to be redistributed within plants from older tissues to active meristems (Black, 1968; Switzer and Nelson, 1972).

Estimates of nutrients other than nitrogen in the stands described above are as follows:

Species, age in years, and treatment	Source	Ca	K	Mg	P
		(Pounds per acre)			
Loblolly pine					
Age 5					
Unfertilized	White and Pritchett (1970)	42	31	15	12
Fertilized	White and Pritchett (1970)	53	39	19	14
Age 20					
Unfertilized	Switzer and Nelson (1972)	80	87	21	17
Age 30					
Unfertilized	Ralston and Prince (1965)	104	105	—	16
Unfertilized	Switzer et al. (1968)	113	118	36	20
Slash pine					
Age 5					
Unfertilized	White and Pritchett (1970)	71	53	28	23
Fertilized	White and Pritchett (1970)	98	73	40	34

Loblolly data are for aboveground biomass only, whereas slash data are for both roots and aerial organs.

According to Switzer and Nelson (1972), most nutrients accumulate in the L, F, or H layers of the forest floor during the first 20 years of a loblolly stand's life. Their synthesis showed that the forest floor then contained 71 pounds of calcium, 14 of potassium, 14 of magnesium, and 8 pounds of phosphorus per acre. About 55 percent more nitrogen than calcium had accumulated.

The portion of each nutrient's total fund (in aboveground parts) that was cycled during the 20th year was estimated by Switzer and Nelson (1972) as follows: potassium, 28 percent; nitrogen, 23 percent; phosphorus, 19 percent; magnesium, 15 percent; and calcium, 7 percent. The greater proportional release of potassium than of other nutrients is in agreement with Curlin's (1970) observation that fresh litter surrenders its residual potassium in a relatively short time—probably because potassium is not immobilized in organic compounds in cells or cell walls. The relative ease with which potassium is leached from the litter makes it more liable than other metallic ions to removal in ground water.

Cycling may be influenced to some extent by cultural practicies such as site preparation, which alters competition and drainage, or by controlled burning of forest litter. Burning ensures early return of metallic ions to the soil, but it releases most of the nitrogen in the litter to the atmosphere. The loss of nitrogen may not be as serious as once supposed. Jorgensen and Wells (1971) found that annual controlled burning markedly enhanced the ability of Bladen and Bayboro soils from South Carolina to fix atmospheric nitrogen in the laboratory. Moreover, soils on annually burned plots contained 1,273 to 1,483 pounds per acre of additional nitrogen after 10 years in the 0-4 inch layer while unburned plots contained 778 to 868 pounds less. These authors thought burning improved the environment for nitrogen-fixing microorganisms by releasing inorganic nutrients and by promoting more favorable soil moisture and surface temperature regimes through reduction of litter and minor vegetation.

A better knowledge of nutrient cycling is essential to the study of fertilization, but data from unfertilized stands will not reliably indicate the quantity of individual elements in the various segments of the cycle. Therefore, this information should be collected from ongoing fertility studies.

FERTILIZATION

Considerable literature has accumulated on growth and quality responses of southern pines to applications of one or more nutrient elements since Paul and Marts (1931) found that commercial fertilizers increased growth of 100+ year-old longleaf pines and influenced the quality of the wood. Many of the publications contain insufficient information on the nutrient status of the soil before the fertilizers were applied. Moreover, many of the trials were with single elements or with fixed combinations of elements and consequently are of little value in determining the total nutrient requirements of the particular species on the site where the test was made. Often the researchers did not attempt to determine what happened to the added nutrients, whether the treatments actually increased nutrient uptake by the pines, or if fertilization stimulated competing vegetation at the expense of the pines. They were satisfied to fertilize the ecosystem and measure the response of the commercial crop. Such practices led to the mistaken notion among many practicing foresters that southern pines are insensitive to level of soil fertility and do not respond to commercial fertilization.

Despite shortcomings, studies of these pioneers proved that commercial fertilizers, if applied on the right soil and at the right time, will produce economically attractive returns. As a result, fertilizers—especially phosphorus— have been applied commercially to southern pine stands in limited areas where a definite need for them has been demonstrated. Emphasis in research has also shifted from determining if southern pines respond to nutrient additions. Rather, investigations now tend to deal with the amounts and kinds of fertilizers required for optimum or maximum pine growth on particular soils, and with the changes in stand volume, quality, and geometry that accrue from various levels and combinations of soil nutrients.

Nitrogen

Nitrogen nutrition of southern pines is more complex than is the nutrition of other major elements. Nitrogen is essential to the breakdown of organic matter, and large quantities may be immobilized for considerable periods in this activity. Also, pine growth responses to nitrogen are often dependent on the addition of one or more other nutrients. A further complication is that nitrogen assimilation may be more closely coupled with carbohydrate reserves in the plant than is the assimilation of other elements. Finally, nitrogen may be supplied in several forms.

A number of authors have reported increases in basal area or diameter growth of southern pines from a single application of 20 to 300 pounds of nitrogen per acre (Jackson and Cloud, 1958; Zahner, 1959; Walker and Youngberg, 1962; Youngberg et al., 1963; Moehring, 1966; Farmer et al., 1970). Responses were usually greatest in the first year; they seldom continued beyond the third growing season, but the advantage gained initially persisted through the final measurement. Pegg (1966) found that bole form of loblolly pine was improved by nitrogen fertilization. None of these authors reported measurable increases in height. The amount of nitrogen required to obtain the responses was not adequately tested. Zahner (1959), however, observed no additional gain in growth from increasing the application rate to 300 from 100 pounds per acre.

Volumes were not reported by these authors. The differences in diameter and basal area growth reported by Zahner (1959) and Farmer et al. (1970) suggest that cubic-foot increment was speeded by 20 to 30 percent during the 5 years following treatment.

In contrast to the responses reported above, Pritchett and Robertson (1960) and Maftoun and Pritchett (1970) found that 300 to 800 pounds per acre of nitrogen applied to pots or to seedlings at planting was in some degree toxic to slash pine on Leon and Lakeland soils in Florida. They thought the soils were inadequately buffered to permit the addition of these quantities in a single application. In Louisiana, Linnartz (1961) found that nitrogen alone depressed 3-year growth of loblolly pine on flatwoods and upland Coastal Plain soils unless phosphorus was also supplied or had been added earlier when the sites were under cultivation. His results suggested an imbalance between elements as the cause of the negative response to nitrogen. He applied the fertilizers when the trees were planted.

In Florida, Pritchett and Smith (1972) also found that nitrogen alone had little effect on growth of slash pine in the first 3 years after planting. Application of 80 pounds per acre of nitrogen (as ammonium nitrate) increased response to phosphorus fertilization on wet but not on better drained sites. The fertilizer was broadcast in bands along the rows 1 to 2 months after the trees were planted.

None of the studies adequately determined the magnitude of response that can be expected from nitrogen fertilization when other nutrients are at optimum levels, as the most comprehensive of them tested only a limited number of fertilizer combinations.

Because young pines are not able to compete advantageously with other vegetation for added nitrogen, a number of investigators suggest that fertilization should be deferred until the stand has a closed canopy (Bengtson, 1971; Maki, 1960; Malac, 1968; Farmer et al., 1970). But there is no unanimity as to when in the life of a closed stand nitrogen should be supplied. Switzer et al. (1968) thought it should be added when the trees are increasing their biomass of limbs and foliage at the fastest rate, or between 7 and 20 years for loblolly pine. Applications during this period would coincide better with maximum needs of the stand than ones made earlier or later. Other authors (Malac, 1968; Stoltenberg and Phares, 1968) have suggested applying nitrogen a few years before final harvest, so as to minimize carrying charges on the investment. This approach, too, appears to have merit in light of the short time that an application increases growth.

Stocking level becomes important in fertilization of closed stands. Curlin (1963) reported that basal area growth of individual shortleaf pines in stands thinned and fertilized with nitrogen was up to 300 percent greater than in untreated stands. Nitrogen alone increased growth up to 40 percent in unthinned stands. Curlin concluded that stand density at time of application must be low enough to allow growth to proceed unhindered. However, Weetman (1968) found that thinning did not affect the response of black spruce, *Picea mariana* (Mill.) B.S.P. In 12- to 14-year-old slash pine plantations, Malac (1968) found that stocking levels between 300 and 900 trees per acre had no significant effect on response of individual trees to nitrogen. Volume growth per acre was promoted most in the denser stands, because they contained more trees. Malac concluded that fertilization might be most profitable if stocking was between 200 and 500 stems per acre. Undoubtedly, he was thinking in terms of stands at or near the same age as those he studied. The conflicting results of the various authors suggest that much remains to be learned on the relationship between stand density and response to nitrogen fertilization.

Most knowledge of southern pine responses to combination of elements has been gained from greenhouse or nursery studies. The findings provide valuable leads but must be verified in field experiments.

From pot experiments on sandy soils of west Florida, Brendemuehl (1968) concluded that slash, sand *(P. clausa* (Chapm.) Vasey), and longleaf pines grow best if the N/P ratio in added nutrients is about 1. Nitrogen alone had little effect. McKee (1973) found that optimum N/P ratio for slash pine in pots of Caddo silt loam from the flatwoods of Louisiana increased as more nitrogen was supplied. He concluded that a ratio on the order of 2 to 1 was desirable when nitrogen was supplied at a rate of 225 pounds per acre.

Nitrogen has a number of effects on phosphorus uptake. The most striking in agronomic crops is increased growth of roots, which brings the plant into contact with a greater quantity of nutrients (Grunes, 1959). Nitrogen also improves nutrient uptake by increasing the metabolic activity of roots and consequently the root exchange capacity and excretion of organic acids that solubilize phosphorus (Grunes, 1959). Inorganic nitrogen may also mobilize phosphorus in the soils to some extent. Beaton et al. showed that ammonia tends to solubilize phosphorus in forest humus.[4]

Nitrogen has interacted with potassium in some experiments. Benzian and Freeman (1967) found that concurrent application of nitrogen and potassium increased nutrient content and reduced frost-susceptibility of western coniferous seedlings in nursery and transplant beds in England. Brendemuehl (1968) reported that longleaf seedlings in pots of Lakeland sand topsoil grew best when supplied with a complete fertilizer equivalent to 150 pounds of N, 300 pounds of P, and 75 pounds of K per acre.

At least in the first rotation under intensive soil management, it may be more practical to release the nitrogen in the soil organic matter than to supply commercial fertilizers. Woodwell (1958) suggested this approach for pond pine *(P. serotina* Michx.) growing on pocosin soils in North Carolina. He thought activity of aerobic bacteria, with resulting release of organic nitrogen, could be increased by draining the site, reducing soil acidity, and correcting deficiencies of other nutrients. The approach deserves evaluation not only in the pocosins but also on the poorly drained flatwoods soils, which are characterized by a high C/N ratio (20 to 1) and approximately 3 to 4 percent organic matter in the 0- to 4-inch layer (U.S. Soil Conservation Service, 1966).

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[4] Beaton, J. D., Harapiak, J. T., Speer, R. C., and Gardiner, R. T. Release of plant nutrients from forest soil humus treated with nitrogen and sulphur fertilizers. Agron. Abs., Annu. Meet. Am. Soc. Agron., p. 103. 1969.

One of the most bothersome aspects of pine nutrition is the apparent low recovery of applied nitrogen. McKee and Sommers (1971) found that 3-year-old slash pine seedlings on Beauregard silt loam recovered only about 25 percent of the nitrogen from a single application of 150 or 300 pounds per acre. Baker (1971) reported that pines and herbaceous vegetation in a 3- to 4-year-old loblolly pine plantation recovered up to 14 percent from a single application and 24 percent from two applications several months apart. An additional 8 percent was found in pine roots and soil. Levels of recovery in both studies agree roughly with Waring's (1969) estimate of 25 percent recovery by 5½ year-old *Pinus radiata* in Australia. Nothing was found in the literature on nitrogen recovery of older stands.

Agronomic crops usually recover 2/3 to 3/4 of ^{15}N in carefully controlled experiments (see Allison, 1966; and Terman and Brown, 1968). Similar definitive studies have not been made with southern pines.

Part of the low recovery ratio in field experiments may result from the high C/N ratios of organic matter in forest soils. This condition leads to severe competition from soil microorganisms for added nitrogen. On soils containing 3 to 4 percent organic matter, 1,000 to 1,500 pounds of nitrogen per acre would be required to lower C/N ratios to a stable base of about 10 to 1. Research is needed to determine the fate of applied nitrogen and to establish if, indeed, important amounts are tied up in the breakdown of soil organic matter.

Finally, nitrogen may be supplied in several forms. Pines are able to utilize both ammonium and nitrate forms (Addoms, 1937); Overrein, 1967; Carrodus, 1969; McFee and Stone, 1968). The choice of a carrier should therefore depend in part on soil factors. The nitrate ion is more mobile and more readily accessible to roots in acid soils, whereas the ammonium ion is more mobile in alkaline soils (Russell, 1961; Black, 1968). Some authorities—for example, Steinbrenner (1968) and Watkins and Strand[5]—advocate urea as a carrier because of its high nitrogen content (45 percent). Urea hydrolyzes rapidly, yielding gaseous ammonia, if soils contain sufficient organic matter to support a high indigenous microbial population (Chin and Kroontje, 1962; Roberge and Knowles, 1968). Loss through volatilization is reported to be as high as 50 percent in forest humus (Overrein, 1970). However, when Volk (1970) added urea to a Florida soil on which forest litter had been removed by burning, not more than 2 percent evolved as ammonia gas during the first 7 days after application.

Slow-release carriers, such as soluble metal salts, urea formaldehyde, and coated diammonium phosphate, have been used to reduce leaching (Strand and Austin, 1966; Walters et al., 1966; Austin and Strand, 1960; Brown and Volk, 1966). Results were variable and depended on environmental factors peculiar to each study. Hydroamides or weakly dissociated nitrogen salts have been suggested as carriers (Wright, 1959), but no reports of their use in forestry were found.

Research on carriers for West Gulf Coastal Plain soils should be deferred until more is learned of the pines' needs for and response to nitrogen under field conditions.

Phosphorus

Pines respond to applications of phosphorus on a wide range of soils in temperate climates throughout the world (Gentle and Humphreys, 1967; Wiley et al., 1970; Pritchett, 1963). The main complicating factors in the study of pine response are solubility of phosphorus compounds in the soil and placement of the fertilizer. The two are related, and both affect the amount of added phosphorus that is actually available to plant roots.

Solubility of phosphorus compounds was discussed earlier in this paper.

Brendemuehl (1970) thought proper placement was the overriding consideration on Southern Coastal Plain soils. He suggested incorporation into the soil in conjunction with preplanting site preparation. Fertilization by this procedure has often stimulated southern pine growth (e.g., Brendemuehl, 1970; Pritchett and Swinford, 1961; Linnartz, 1961). It has not always been clear, however, how much of the increase accrued from fertilization and how much from site preparation. Surface applications did not stimulate growth of older loblolly pine stands in Arkansas (Zahner, 1959) or of newly planted slash pine in about half of Pritchett and Smith's (1972) trials on better drained soils in the Southeast; these results are consistent with the idea that incorporation is desirable. Conversely, surface applications have usually stimulated slash pine growth on imperfectly and poorly drained phosphorus-deficient soils (Pritchett and Llewellyn, 1966; Pritchett and Smith, 1972; Wells and Crutchfield, 1969).

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[5] Watkins, S. H., and Strand, R. F. Volatilization loss of ammonia N from urea applied to forest soils and forest floor materials. Agron. Abs., Annu. Meet. Am. Soc. Agron., p. 164. 1970.

The level of soil phosphorus required for pine growth is not known. Requirements are influenced by soil characteristics and environmental factors, and there is no universally satisfactory method of measuring availability. Moreover, species vary in their requirements. A number of authors suggest that a general range of 100 to 200 p/m of total mineral phosphorus is optimum for southern pines growing on highly weathered soils (Pritchett, 1968; Richards, 1958; Raupach, 1967). Richards (1958) reported optimum levels of 210 and 150 p/m of total soil phosphorus for loblolly and slash pine, respectively, in Australia. Baur (1959) was quoted by Pritchett and Llewellyn (1966) as proposing 70 p/m of total phosphorus as the critical level for a slash pine plantation in New South Wales, Australia. On sandy flatwoods soils in Florida, Pritchett and Llewellyn (1966) found that slash pine responded to 17 to 35 pounds per acre of phosphorus added as superphosphate when the level of ammonium-acetate-extractable phosphorus in the unfertilized soil ranged from 0.5 to 2.7 p/m. Total phosphorus in these soils ranged from 19 to 74 p/m. Thus, average content of the furrow slice of heavily fertilized plots was 36 to 91 p/m, which is considerably lower than that prescribed by either Richards or Baur for Australia.

Pines on well to excessively drained soils in Pritchett and Llewellyn's (1966) tests did not respond unless nitrogen was also added. The difference in response between flatwoods and better drained soils could not be explained by initial phosphorus levels in the soil. It appears, therefore, that higher levels are required on imperfectly than on well drained soils. Conversion of aluminum to iron phosphate occurs when soil is waterlogged for significant periods of time (McKee, 1970); in addition, trees in poorly aerated soils may be less able to take up the phosphorus that is available.

Foliar analyses are another means of diagnosing phosphorus deficiencies. Pritchett (1968) considered 0.09 to 0.10 percent to be the critical level in needles of 5- to 8-year-old slash pine in Florida, but cautioned that age of tree, age of foliage, position of foliage in the crown, and certain growth-limiting factors would influence the percentages. To minimize the effects of these factors, most researchers follow the procedure of Wells and Metz (1963) and analyze needles from the first flush of the current season's growth collected from the south side of the upper one-third of the crown. Critical concentrations in loblolly pine needles appear to be slightly higher than those in slash needles, or 0.10 to 0.12 percent (Miller, 1966). No close relationships have been established between phosphorus concentrations in foliage and optimum or maximum growth of pines.

A carrier that is relatively insoluble and will equilibrate very slowly may be advantageous in soils low in exchangeable aluminum or other constituents that restrict movement of phosphorus through the profile or have a high capacity to form iron phosphates. Rock phosphate has been found to be a good nutrient source under these conditions (Pritchett, 1963; Richards, 1958; Bilan, 1966; Barnes and Ralston, 1953; Humphreys and Pritchett, 1971). Its availability to pines increases with the citric acid solubility of the material.[6]

Use of rock phosphate in the West Gulf Coastal Plain will probably depend more on relative total costs than on its reactions in the soil, as few soils of the region appear to require a carrier with the unique properties it possesses. For the present, at least, research in this region should concentrate on learning how phosphorus behaves in the soil and how it should be applied for pines to use it efficiently;

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[6] Bengtson, G. W., Sample, E. C., and Lehr, J. R. Factors related to performance of various rock phosphates used as sources of P for Pinus elliottii seedlings. Agron. Abs., Annu. Meet. Am. Soc. Agron., p. 123. 1969.

comparisons between carriers are of secondary importance.

Almost no research has been done to determine how often phosphorus must be applied to maintain optimum or maximum growth. Some researchers believe that enough can be added when the stand is established to satisfy needs for an entire rotation. Current data indicate that responses persist for 5 years or longer on poorly drained soils (Pritchett and Llewellyn, 1966); in 7 to 11 years, superphosphate, but not rock phosphate, had moved to depths greater than 8 inches (Humphreys and Pritchett, 1971). Tests are needed to provide similar information for other soils and to learn if growth is further enhanced or initial response is prolonged by additional applications as the stand develops. It is also necessary to determine how established stands respond to initial applications of phosphorus either alone or in combination with other elements.

Potassium, Calcium, and Magnesium

Only under rather unusual circumstances has fertilization with the major macro-cations, potassium, calcium, and magnesium, markedly increased growth of pines.

The most spectacular responses to potassium fertilizers have been on highly leached outwash sands of the Northeast (Kawana et al., 1969; Heiberg et al., 1964; Fornes et al., 1970; Heiberg and White, 1951; Madgwick et al., 1970). These soils have extremely low exchange capacities and very little native potassium.

In a 7-year-old loblolly pine plantation on Piedmont soils in South Carolina, Wells (1970) obtained no response to applications of 120 and 240 pounds per acre of potassium with or without the addition of 200 pounds per acre of nitrogen. Moreover, in trials by Pritchett and Smith (1972) potassium applied with nitrogen and phosphorus did not increase three-year growth of slash pine significantly more than did the two companion nutrients alone. The reason for this lack of response may be that potassium is one of the most mobile of ions in plants (Bukovac and Wittwer, 1957) and hence that current needs of active meristems may be largely supplied through redistribution within the plant (Switzer and Nelson, 1972).

Deficiencies in closed stands apparently can be diagnosed easily by foliar analysis (Walker, 1955; Madgwick, 1964). No clear evidence has been discovered, however, of potassium deficiencies in stands of southern pines.

Measurements of the biomass of pine stands (Ralston and Prince, 1965; White and Pritchett, 1970) indicate that calcium nutrition may become critical during the rotation if the initial amount in the soil is not more than 400 to 600 pounds per acre. Calcium and magnesium deficiencies, however, are less common than potassium deficiencies, and none have been reported for pines in the West Gulf region.

La Bastide and van Goor (1970) found that low levels of calcium and magnesium were limiting growth of slash pine on many soils in Brazil. They reported minimum requirements of about 1.5 milliequivalents per 100 grams of soil for calcium and magnesium combined (or 600 pounds per acre of calcium, if their estimate was based on depth of a furrow slice). A number of soils sampled in the Coastal Plain fall below this level (U.S. Soil Conservation Service, 1966).

In Germany, liming has doubled or tripled the growth of Scotch pine *(P. sylvestris* L.) and spruce *(Picea abies* (L.) Karst.) (Stoeckeler and Walker, 1963). It should be noted, however, that these results are for true spodsols that are very acid, are low in bases, and have thick organic surface horizons that tie up large amounts of nutrients. Moreover, establishment of perennial lupines was necessary for maximum response to lime. Much of the apparent response to calcium may actually be a response to other nutrient ions whose cycling is accelerated by liming (Mayer-Krapoll, 1956).

Calcium deficiencies are reported to retard growth of the terminal bud, reduce the size of stem tips and leaf cross sections, and decrease primary tissues in the stems of loblolly pines grown in solutions (Davis, 1949). Voigt et al. (1958) stated that calcium and magnesium deficiencies of seedlings in the field result in an intense yellowing of the outer portions of the needles. Sucoff (1961, 1962) noted similar deficiency symptoms on loblolly and Virginia *(P. virginiana* Mill.) pine in sand culture. Needle color has been suggested as a means of diagnosing such deficiencies (Lyle, 1969).

A number of papers indicate that lime is toxic to pine (Gilmore and Boggess, 1963; Bengtson, 1968). High levels of calcium and pH have been reported to cause chlorosis (Wilson, 1959; Shoulders and Czabator, 1965).

Lyle and Adams (1971) observed that the cation balance may be critical for root growth of loblolly pine seedlings in water culture and greenhouse pot studies. They concluded that liming may be necessary for root development in young loblolly pine plantations fertilized with high-analysis, low-calcium fertilizers.

Application of lime has several implications for plantation management other than calcium nutrition. Its use to enhance organic matter breakdown and phosphorus availability has been discussed in other sections. Lime may be needed to reduce levels of toxic elements such as manganese and aluminum (Black, 1968) and to adjust base saturation of the exchange complex. Solubility of aluminum and manganese are strongly influenced by pH. How important these factors are to pine nutrition remains to be determined. Experience with agronomic and horticultural crops (Jackson, 1967) indicates that they should be explored.

Certainly, research is needed on cation nutrition of southern pines on flatwoods and upland Coastal Plain soils. These investigations, at least for the present, should seek to determine growth responses to addition of calcium and potassium after phosphorus and nitrogen have been adjusted to near optimum levels.

Minor Elements

The minor mineral elements have only recently gained the attention of forest researchers in the South. Current literature records no universal response of any species of southern pine to additions of any or all of the minor elements at planting or later. In a series of uniform fertilizer tests in the Southeast, all other essential elements stimulated early growth of slash pines on 3 to 28 sites that had also received nitrogen, phosphorus, and potassium and depressed it on 4 other sites (Pritchett and Smith, 1972). Van Lear and Smith (1972) studied minor mineral nutrition on three Southeast Coastal Plain soils in more detail. On Leon fine sand, supplementary copper was required before potted slash pines responded to nitrogen and phosphorus fertilization. Macronutrients supplemented with copper, manganese, and zinc produced greatest growth on Lakeland sand. On Bladen fine sandy loam, micronutrient supplements were unnecessary for maximum growth response to additions of 100 p/m of nitrogen and 400 p/m of phosphorus.

Van Lear and Smith's (1972) investigation supports Stone's (1968) observation that deficiencies of several minor elements may be induced by heavy liming or phosphorus fertilization. Nursery seedlings threatened by imbalances of lime and phosphorus have been salvaged by applying iron chelate (Shoulders and Czabator, 1965).

Soil organic matter is an important reservoir for chelated or nonionic forms of minor elements (Wallace, 1962). Its ability to act as a chelating agent is dependent on the type of organic compound present, valence of the ion chelated, bonding energy of the metal, ionic strength of the system, and soil pH. Complexing agents may have a direct physiological influence on plant growth as well (Schnitzer, 1969). In general, the strength of the organic-metal complex increases with valence and molecular weight. For example, fulvic acid forms a more stable complex with ferric iron than with calcium by a factor of 1×10^4 (Schnitzer and Hansen, 1970). Increasing hydrogen ion activity (i.e., lowering pH) improves the stability of metal-organic complexes, and many soil chelates break down if acidity approaches neutrality (Wallace, 1962; White, 1970).

In general, humic acids in soil all react similarly with metals, but their activity coefficients differ. Coefficients of individual acids may be important in cyclically submerged soils because of changes in pH associated with reduction and reoxidation.

Research in minor mineral nutrition of pines on flatwoods and upland Coastal Plain soils of the West Gulf should be undertaken only as a need for it is demonstrated through unusual or erratic responses to major elements.

OTHER CONSIDERATIONS

In their response to mineral nutrients, trees are influenced by their physiological condition and genetic makeup, and also by various environmental conditions. Such effects must be considered in planning and interpreting research. A brief summary of these relationships is therefore included.

Some physiological processes and conditions of southern pine have seasonal patterns, or vary with age of the tissue. For example, as needles of loblolly pine increase in age, their nitrogen, phosphorus, and potassium contents tend to decrease, while their calcium and magnesium contents increase. Moreover, about one-half of the nitrogen, phosphorus, and potassium is translocated to other organs immediately before abscission. Calcium and magnesium remain in the needles (Wells and Metz, 1963; Miller, 1966). The most reliable indexes of nutrient deficiencies in loblolly pine can be obtained by sampling the current year's needles for phosphorus in August or September and for cations in December through March; needles should be sampled for nitrogen in June through September of their second growing season (Wells and Metz, 1963). Considerable research is needed to develop completely satisfactory methods for appraising nutrient status of southern pines through needle analyses.

Organic constituents of trees also vary seasonally. Hepting (1945) found that carbohydrate reserves in shortleaf pine were low in late summer and highest in midwinter. Data for slash pine in Louisiana indicate a similar trend. Carbohydrate levels there were high in late fall and early spring and low in late summer (McKee and Sommers, 1971); these plants were not sampled at other seasons. In red pine, reducing sugars in needles and soluble proteins in needles and bark were high in winter and low in summer (Pomeroy et al., 1970).

The seasonal change in carbohydrates may influence timing of nitrogen application, since ammonium nitrogen cannot accumulate in plants (Webster, 1959) and therefore must be held in some organic compound. Carrodus (1969) indicated that available carbohydrates largely control the utilization of inorganic nitrogen. Conversely, timing of nitrogen fertilization has influenced the distribution of the total photosynthate among plant organs (Priestley, 1972). In a Louisiana study, however, application of nitrogen in late October and in early April produced similar responses in growth and nutrient uptake of 3-year-old slash pines on Beauregard silt loam soil (McKee and Sommers, 1971). In this study, the seedlings recovered only 25 percent of the applied nitrogen. Relationships between season of application and carbohydrate levels of roots will merit further study when ways have been found to improve nitrogen utilization of southern pines.

Because individual components of the environment are difficult to isolate in the field, growth chambers are often used to study the independent effects of light intensity and temperature on current rates of nutrient uptake by pines. In one such study, uptake and transport of radioactive phosphorus to needles of 1-year-old slash pines decreased with increasing day/night temperatures over the range 59/50 to 95/86 degrees Fahrenheit and with decreasing light intensity over the range 2,500 to 1,200 foot candles (McKee, 1972). The rate of phosphorus uptake was partly explained by levels of ethanol-soluble carbohydrates in the roots.

Additional research is needed to clarify the effects of light and temperature on ion flux into and through seedlings and older trees, as well as their effects on carbohydrate reserves and the relationships between carbohydrates and ion flux. The complexities in such investigations are illustrated by the work of Barnes and Berry (1969). They found that carbohydrate contents of white pine (*P. strobus* L.) seedlings in growth chambers were less affected by light intensity than by temperature, but that sugar content of tissue from field-growing seedlings was higher on sunny than on cloudy days. Research into environmental effects on physiology will require careful design, because individual trees may respond differently from stands.

That density and structure of the stand affect response to nitrogen fertilizers was noted earlier. These factors also appear to be important with other elements. Ryker and Pfister (1967) found that 40-year-old white pine did not react to a mixed N-P-K fertilizer until the stand was thinned.

Root environment affects mineral nutrition by influencing distribution of roots in the soil as well as the plant's ability to take up nutrients. Lorio et al. (1972) found that microrelief altered the distribution of roots of a 40-year-old loblolly pine stand on an imperfectly drained flatwoods site in central Louisiana. Roots of all sizes were abundant to greater depths on mounds than on surrounding flat areas. The change in rooting patterns was explained in part by differences in water regimes and soil texture between mounds and flats. Schultz (1969) showed that slash pine seedlings in pots took up less nutrients and grew slower under waterlogged conditions than when well aerated. Burton (1971) found that growth and nutrient uptake of loblolly pine seedlings decreased with the length of time that the soil surface was submerged. Other authors have also observed that levels of nutrients in pine foliage are depressed by poor aeration of roots (Miller, 1966; Wells and Metz, 1963).

Symbiotic relationships between pines and mycorrhizae-forming fungi influence, and are influenced by, physiological condition of the trees and their uptake of mineral nutrients. A few aspects that are particularly important to pine nutrition are considered here. The degree of fungus infection on pine roots is related to levels of ethanol-soluble carbohydrates (Hacskaylo, 1959; Björkman, 1970). A close relationship has been found between mycorrhizal infection and phosphorus uptake (Ritter and Lyr, 1965; Mejstrik, 1970; Henderson and Stone, 1970; Shoulders, 1972). Moreover, Kramer's (1951) discovery that uptake of phosphorus by mycorrhizae requires metabolic energy further demonstrates that the carbohydrates supplied by the host are of mutual benefit to both symbionts.

Balance of nitrogen, phosphorus, and potassium influences development of mycorrhizae. Nutrient imbalances as well as heavy fertilization that promotes luxuriant growth depresses the number of these organs on roots (Hacskaylo, 1959; Lister et al., 1968).

Soil microbial activity and soil chemistry are affected by pine root exudates including carbohydrates, organic acids, amino acids, and vitamins (Smith, 1969). Effects of these exudates on nutrient uptake are not known.

Application of fertilizer can also affect the physiological processes and the way in which a plantation will respond to climate. Keller (1968) reported, for example, that fertilization tends to increase rate of photosynthesis but that unbalanced amounts depress CO_2 uptake. Etter (1969) reported that high levels of nitrate nitrogen in nutrient solutions reduced drought-resistance of lodgepole pine (*P. contorta* Dougl.) seedlings growing in an artificial soil. The loss of resistance was related to a lessening of carbohydrates in leaves and roots. Pharis and Kramer (1964) found that too much and too little nitrogen in culture solutions depressed survival of loblolly pine seedlings during drought; high nitrogen levels were toxic, while intermediate levels improved drought-resistance. Parker (1969) noted that addition of potassium and phosphorus tended to improve drought hardiness in a number of woody plants.

Schmehl (1967) thought that nitrogen levels influenced "hardness" of herbaceous plants by changing growth patterns and competition for food reserves. Moderate additions increased the leaf area and total carbohydrate fixation, but excessive applications stimulated top growth at the expense of root reserves.

Complex responses of stands to fertilizer are difficult to anticipate, but careful observations should be made especially when the trees are under environmental stresses such as those imposed by drought or waterlogging.

Foster (1968) indicated that fertilizers may modify the severity of damage from forest pests. Froelich et al. (1966) found that high incidence of *Fomes annosus* infection was associated with low organic matter, high pH, a sandy texture, and a sparse grass understory. The impacts on insect and disease susceptibility of stands may, in the long run, be a major factor in adoption or rejection of a particular fertilization practice.

Almost invariably, fertilization at planting stimulates a profuse growth of grasses and other herbaceous plants. Few researchers have faced squarely the impact of competition from these plants for nutrients and growing space. Derr (1957) showed that fertilization increased early growth of planted longleaf pine only if competition was adequately controlled. Box et al. (1966) reported that a fertilized 3-year-old loblolly plantation had benefited markedly from three mowings annually, but the combined effects of mowing and fertilizing could not be separated from those of mowing alone. Probably mowing enhanced the response of the pines to the fertilizer. Baker (1973) found that slash pine in a 5-year-old plantation on Lakeland sand in Florida had benefited about as much from fertilization as from complete control of competition. Each treatment increased height growth about 45 percent. In combination, they resulted in a 70-percent increase.

Many authorities, including Schultz (1969), Pritchett and Goddard (1967), Walker and Hatcher (1965), and Zobel and Roberds,[7] believe that southern pines of different genetic backgrounds vary widely in their response to fertilizers. Experience with agronomic crops indicates that this aspect of pine nutrition deserves immediate and thorough investigation. In fact, spectacular gains from fertilization may depend as much on developing strains of southern pines that are unusually responsive as on solving other problems in pine nutrition.

CONCLUSIONS

Emphasis in pine nutrition research in the West Gulf Coastal Plain should be placed on determining how growth is related to various levels and combinations of mineral nutrients, especially nitrogen and phosphorus, and on learning the reasons for these relationships. Such information will give individual landowners a quantitative basis for deciding which practices are feasible for them to adopt. The basic knowledge gained through this approach will be useful in planning new studies with unusually responsive strains.

The research must consider both the soils' abilities to hold nutrients in available forms and the pines' abilities to respond to fertilizers through increased production of merchantable fiber. If results of individual fertilizer trials are to be extrapolated from one soil to another, data are needed on the nature and the components of the exchange complex of individual soils, on the reactions which added phosphorus undergoes in them, and on the cycling of nitrogen through them.

The cycling of nutrient elements by the stand throughout the rotation must be understood if mineral supplements are to be balanced with the nutrient-supplying power of the ecosystem.

Fertilizer trials must determine nutrient levels and balances which optimize growth at different stages of stand development. Ways must be found to increase the efficiency of pines in recovering added nutrients, especially nitrogen, and to ensure that competing vegetation does not utilize added nutrients to the detriment of pines. Soils that immobilize phosphorus fertilizers at the surface must be identified, and techniques developed whereby phosphorus may be supplied to established stands of pine growing on them. Conventional methods of incorporating fertilizers into the soil inflict undue injury on roots of older trees.

Deficiencies of micronutrients may limit pine growth on some soils of the region, especially if macronutrients are at optimum or luxury levels. For the present, at least, research in this area should be limited to situations where fertilization with macronutrients has produced increased or erratic responses.

On many soils in the West Gulf, spectacular gains will not be obtained until geneticists develop strains that are unusually responsive to fertilization. Experience with agronomic crops indicates that this aspect of pine nutrition deserves immediate and thorough investigation.

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Review of current literature establishes that forest fertilization is a proven, accepted management practice in limited areas of the South where lack of one or more mineral nutrients seriously curtails pine growth and where moderate additions of these nutrients markedly increase yields. In most of the South, however, and especially in the West Gulf Coastal Plain, general use will be deferred until amounts, kinds, and schedules of application can be reliably specified for individual soils.

Additional keywords: Fertilization, nutrient cycling, soil fertility.

U. S. Department of Agriculture
Forest Service Technical Report SO-3

Selected Bibliography on Southern Range Management, 1968-1972

H. A. Pearson
C. E. Lewis
G. E. Probasco
G. L. Wolters

The Trail Boss

Southern Forest Experiment Station
Forest Service
U. S. Department of Agriculture

1973

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Pearson, H. A., Lewis, C. E., Probasco, G. E., and Wolters, G. L.

1973. Selected bibliography on southern range management, 1968-1972. South. For. Exp. Stn., New Orleans, La. 50 p. (USDA For. Serv. Gen. Tech. Rep. SO-3)

About 950 entries, classified by subject matter, and with index of authors.

Additional keywords: Livestock, forage plants, wildlife, range ecology, forest grazing.

Selected Bibliography on Southern Range Management, 1968-1972

H. A. Pearson,[1] **C. E. Lewis,**[2] **G. E. Probasco,**[3] **and G. L. Wolters**[1]

Committee on Range Bibliography of Southern Section,
Society for Range Management

This bibliography is the third of a series inaugurated in 1963 for the purpose of recording publications that deal importantly with the forest ranges of the South, and with the livestock and wildlife utilizing this vast resource.

For the first number of the series[4], the compilers appraised all literature that had accrued through 1961. The second bibliography[5] spanned the years 1962-1967. The present list brings up to date the coverage of publications which--with allowance for errors of judgment and inadvertence--should prove most useful to the diverse interests of land managers, stockmen, conservationists, scientists, teachers, and students.

As before, the southern range area is considered to extend from eastern Oklahoma to Virginia, and from southern Kentucky and Missouri to the Gulf of Mexico. Because pasture commonly augments the diets of cattle that subsist chiefly on range forage, pertinent publications on supplemental pastures are included.

The list contains over 950 entries, as compared to 650 for the previous compilation. We think that the increase is chiefly due to expansion both of research and of general interest. Much of the gain is in wildlife publications, which have become so numerous as to require subdivision of that category.

Except for amplification of the wildlife section and minor changes in other sections, the classification is the same as that used heretofore. Publications relating to more than one subject are under the topic of principal concern. Cross-references are suggested at the beginning of some sections.

Sources consulted included books, periodicals, publications of the U. S. Government, and of State agricultural experiment stations, releases of regional organizations and private foundations, and bibliographies with abstracts. Periodicals searched included:

Agronomy Journal
American Forests
American Journal of Botany
American Midland Naturalist
Botanical Gazette
Botanical Review
Crop Science
Ecology
Ecological Monographs
Economic Botany
Forest Farmer
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Forest Science
Gulf Coast Cattleman
Journal of Animal Science
Journal of Forestry
Journal of Range Management
Journal of Soil and Water Conservation
Journal of Wildlife Management
Soil Science
The Cattleman

Several members of the Society for Range Management reviewed an initial draft of the bibliography and supplied additional pertinent references:

E.R. Beaty, Agronomy Department, University of Georgia, Athens, Ga.

N.A. Byrd, Southeastern Area State and Private Forestry, USDA Forest Service, Atlanta,Ga.

C.W. Carter, USDA Soil Conservation Service, Gainesville, Fla.

W.N. Darwin (retired), MacMillan Bloedel Products, Inc., Camden, Ala.

H.E. Grelen, Southern Forest Experiment Station, USDA Forest Service, Pineville, La.

M.L. Hopkins, Kisatchie National Forest, USDA Forest Service, Pineville, La.

A.W. Johnson, Region 8-Southern Region, USDA Forest Service, Atlanta, Ga.

N.E. Linnartz, School of Forestry and Wildlife Management, Louisiana State University, Baton Rouge, La.

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[1] U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Pineville, La.

[2] U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, Marianna, Fla.

[3] U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, Columbia, Mo.

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H.D. Moberly, Department of Economics, Auburn University, Montgomery, Ala.

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FORAGE VALUE

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See also Poisonous Plants, Revegetation, Supplemental Pastures, Feeds and Feeding, Food Habits, and Habitat.

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J.D. Solomon and C.J. Hay

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Annotated Bibliography of the Carpenterworm, *Prionoxystus robiniae*

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This bibliography has been prepared for entomologists, foresters, pest control personnel, and others who wish to refer to literature on the carpenterworm, *Prionoxystus robiniae* Peck (Lepidoptera: Cossidae).

The insect, the larvae of which cause severe economic loss by tunneling in the trunks of hardwood timber trees, was originally described in 1818 and named *Cossus robiniae*. The generic name was subsequently changed to *Xyleutes* Harris, then to *Xystus* Grote, and finally to *Prionoxystus* Grote. Common names include locust moth, locust cossus, locust carpenter moth, goat moth, carpenter moth, carpenter borer, locust tree borer, ash tree borer, and oak carpenterworm.

The carpenterworm is a native of North America and is widely distributed throughout the United States and southern Canada. In the Eastern and Southern U.S. the oaks are its principal hosts. Here and elsewhere, however, green ash, black locust, elm, maple, willow, cottonwood, and occasionally fruit trees and ornamentals are attacked.

The larvae hatch from eggs laid in crevices on the bark and promptly enter first the inner bark and then the sapwood. The larval stage may be completed within 1 or 2 years in the South, but may continue for 3 or 4 years elsewhere. The adult is a large grey moth. Fully grown larvae may be 12 mm in diameter, and their tunnels in the sapwood cause much loss from degrade when infested trees are sawn into lumber.

Over the years, considerable literature has developed. Early contributions were primarily descriptive, and dealt mostly with systematics and with damage and control in shade trees. Only within the past few decades has the carpenterworm's great importance in hardwood forest stands been recognized.

No previous attempt has been made to compile a complete bibliography, but Munro and Fox (1934) included 48 references in their paper on biology and control. The present bibliography is arranged in alphabetical order by author and is intended to cover all technical literature through 1972. Most annotations summarize the salient information in each publication but for literature that presents only brief or general treatment the annotation consists of a few keywords to characterize the content. Citations from USDA Cooperative Economic Insect Reports are presented in abbreviated form on page 2.

Readers who are beginning a study of the carpenterworm are particularly directed to papers by Hay, Morris, Munro, and Solomon. Older publications deserving attention are those by Burke, Doten, Felt, Fetch, Grote, and Packard. Information on specific aspects of the insect may be located through the subject index.

The initial sources of reference were the authors' files and the various forestry and entomological journals. Other important sources were *Biological Abstracts, Forestry Abstracts, Review of Applied Entomology, Zoological Record*, and *Index to the Literature of American Economic Entomology*. Citations in specific publications provided additional titles. Though considerable care was taken, there probably are omissions; notification of these will be appreciated.

Some of the references deal with uses of pesticides no longer approved by the U. S. Department of Agriculture. Before any pesticide is applied, its current registration should be checked with responsible State or Federal authorities.

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Tabulated annotations from USDA Cooperative Economic Insect Reports

Year	Vol., issue, and page No.	Hosts	State	Comment
1954	4(9):179	Turkey oak	Fla.	Death of several trees
	4(21):434	Oaks	N. Car.	Damaging trees
	4(27):612	Oaks	Va.	Dead and dying trees, most infested
	4(38):873	Oaks	Miss. & Va.	Damaging trees
	4(49):1062	Pecan	Tex.	Light to medium infestation
1956	6(52):1145	Shelterbelt trees	Mont.	Becoming of economic importance
1957	7(23):447	Oaks	Miss.	Damaging trees
1958	8(6):98	Pecan	S. Car.	Extremely serious damage
1959	9(3):24	Ash, cottonwood, elm boxelder, Chinese elm	Mont.	Attacks noted
	9(24):511	Pecan	S. Car.	15-20 large holes noted in some trees
	9(34):794	Elm	Calif.	A local problem
	9(48):1021	Calif. black oak	Calif.	Severe damage and killing
1960	10(15):250	Oak	Calif.	Medium infestation
	10(26):566	Elm	S. Dak.	Attacks noted
	10(35):813	Elm	Calif.	Medium infestation
	10(45):1055	Chinese elm	Calif.	Heavy infestation
1961	11(29):668	Ash	N. Dak.	Killing trees in 7-year-old shelterbelt
	11(43):1004	Shelterbelt trees	Mont.	Severe damage
1962	12(7):82	Pecan	Ala.	Moderate 20A infestation
	12(14):310	Calif. live oak	Calif.	Locally heavy
1962	12(14):329	Ash	N. Dak.	Severe infestations
	12(26):710		N. Dak.	Male moths taken at light trap
1963	13(3):29	Coast live oak	Calif.	Increase in infestation during 1962
1964	14(11):192	Peaches	Calif.	Medium infestation
	14(16):346	Poplar and oak	N. Dak.	Some damage in shelterbelts
		Shade trees and ornamentals	Colo.	Noted as a pest
	14(26):695	Ash	N. Dak.	Attacks noted
	14(31):870	Cherry	Wash.	Attacking winter-injured trees
	14(31):889	Oaks	Ind.	Considerable damage
	14(35):1003	Elm	Colo.	Attacks noted
1965	15(12):223	Cherry	Wash.	Damaging winter-injured trees
	15(16):354	Oaks	Central States	Damage and degrade severe
	15(20):486	Ash	Calif.	Pupae heavy locally in trunk
	15(51):1325	Boxelder	Calif.	Larvae heavy locally in trunks
1967	17(14):261-2	Hardwoods	Mo.	Serious log and lumber degrader
			Mont.	Abundant
		Cottonwood, walnut, ash	Calif.	Damage noted
	17(16):311	Pecan	Ga.	Heavy infestations
1968	18(13):246	Deciduous trees	Mont.	Destructive pest of deciduous trees
1969	19(13):229	Shade trees		
	19(26):476		Mont.	Increasing number
		Elms	Neb.	Severe larval damage
1969	19(36):706	Willows	Calif.	Heavy damage
1970	20(14):222	Shelterbelt plantings and ornamental trees	Mont.	Major pest
1971	21(16):284	Hardwoods	Mo.	Most destructive borer
	21(24):416	Green ash and Siberian elm	S. Dak.	Heavy damage

1. Anonymous. 1971. CONTROL OF BORERS IN PLANTED TREES IN THE PRAIRIE PROVINCES. Can. Dep. Agric. TN Pam. 2, 15 p.
The carpenterworm is a serious pest of trees planted for shade, ornamental, and windbreak purposes. Information on hosts, damage, signs of attack, stages, life cycles, prevention, and control.

2. Abrahamson, L. P., and McCracken, F. I. 1972. INSECT AND DISEASE PESTS OF SOUTHERN HARDWOODS. *In* Proc., Southeast. Hardwood Symp. (1971), p. 80-89. USDA For. Serv., Southeast. Area State and Priv. For., Atlanta, Ga.
In the Midsouth, carpenterworms spend up to 2 years constructing 6-inch long galleries in the trunks of oaks. The female sex pheromone is being investigated as a potential control.

3. Anderson, R. F. 1960. FOREST AND SHADE TREE ENTOMOLOGY, p. 325-327. Wiley & Sons, N.Y.
Biology, damage, and control.

4. Bailey, J. S. 1883. ON SOME OF THE NORTH AMERICAN COSSIDAE, WITH FACTS IN THE LIFE HISTORY OF COSSUS CENTERENSIS LINTNER. *In* USDA Div. Entomol. Bull. 3, p. 49-55, plates I, II.
P. robiniae *attacks oak, willow, and locust from California east to New York. Forms of* P. robiniae *are discussed.*

5. Baker, W. L. 1972. EASTERN FOREST INSECTS, p. 388-389. USDA Misc. Pub. 1175.
Biology, damage, control.

6. Barnes, W., and Benjamin, F. H. 1923. PRIONOXYSTUS ROBINIAE. Contrib. Nat. Hist. Lepid. N. Am. 5: 94-95.
Specimens vary little in appearance within a locality but show remarkable variation among geographic areas. Three races are described: mixtus, subnigrus, *and* flavotinctus.

7. Barnes, W., and McDunnough, J. H. 1911. REVISION OF THE COSSIDAE OF NORTH AMERICA. Contrib. Nat. Hist. Lepid. N. Am. 1(1): 3-35.
Two subfamilies of Cossidae, Hypoptinae and Zeuzerinae, are given and P. robiniae *is placed in Zeuzerinae. Systematics of the Cossidae are discussed and a key to the genera of the two subfamilies is presented.*

8. Beal, J. A. 1957. INSECT RESEARCH TO INSURE AND MAINTAIN TIMBER QUALITY. *In* Proc. Timber Quality Conf., p. 1-12. USDA For. Serv. For. Prod. Lab., Madison, Wis.
The greatest impact of trunk-boring insects on quality material is among the hardwoods in the eastern half of the country, especially in the Mississippi Valley. Research on controls is urgently needed.

9. Beal, J. A., Haliburton, W., and Knight, F. B. 1952. FOREST INSECTS OF THE SOUTHEAST: With special reference to species occurring in the Piedmont Plateau of North Carolina, p. 64-66, plate 12. Duke Univ. Sch. For. Bull. 14.
The carpenterworm has attracted most attention as a pest of shade and ornamental trees, but it also does much damage in forest stands. Briefly describes life stages, biology, hosts, and damage.

10. Blickenstaff, C. C. 1970. COMMON NAMES OF INSECTS, p. 4. Entomol. Soc. Am. Comm. on Common Names of Insects.
The approved common name of P. robiniae *is "carpenterworm."*

11. Boisduval, J. A. 1852. LEPIDOPTERES DE LA CALIFORNIE. Ann. Soc. Entomol., ser. 2, 10: 323.
Description, hosts.

12. Borror, D. J., and DeLong, D. M. 1954. INTRODUCTION TO THE STUDY OF INSECTS, p. 533. Holt, Rinehart, and Winston, N.Y.
Biology, key.

13. Borror, D. J., and White, R. E. 1970. A FIELD GUIDE TO THE INSECTS OF AMERICA NORTH OF MEXICO, p. 242-243, plate 12. Houghton Mifflin Co., Boston.
Description.

14. Boyd, W. M. 1945. INJURIOUS INSECTS OF NEW JERSEY NURSERIES, p. 138-139. N. J. Dep. Agric. Circ. 355.
Biology, damage.

15. Boyd, W. M. 1953. INSECTS OF IMPORTANCE IN NEW JERSEY NURSERIES, p. 167-168. N. J. Dep. Agric. Circ. 390.
Biology, damage, control.

16. Brimley, C. S. 1938. THE INSECTS OF NORTH CAROLINA, p. 313. N. C. Dep. Agric. Div. Entomol., Raleigh.
Moth emergence, distribution.

17. Britton, W. E. 1926. BORERS IN RELATION TO CAVITIES IN TREES. Tree Talk 7: 11-13.
P. robiniae *makes large cylindrical galleries in the trunks of ash, elm, oak, maple, and locust. Wounds should be dressed promptly to promote healing and prevent decay.*

18. Britton, W. E. 1933. PLANT PEST HANDBOOK FOR CONNECTICUT, I. Conn. Agric. Exp. Stn. Bull. 344, p. 126.
Damage, hosts.

19. Bromley, S. W. 1944. CONTROLLING BORERS IN TREES. Horticulture 22: 412.
Can be controlled by "cutting out," fumigation of galleries, and wrapping trunks.

20. Brown, H. P., and Panshin, A. J. 1940. COMMERCIAL TIMBERS OF THE UNITED STATES, p. 283-285. McGraw-Hill, N.Y.
Impact.

21. Brown, L. R., and Eads, C. O. 1965. A TECHNICAL STUDY OF INSECTS AFFECTING THE OAK TREE IN SOUTHERN CALIFORNIA, p. 60-63. Calif. Agric. Exp. Stn. Bull. 810.
Illustrated description of carpenterworm life stages with notes on life history. Control measures include mechanical methods (such as poking into tunnels with a wire), application of a chemical or spray, and injection of a fumigant into the tunnels.

22. Browne, F. G. 1968. PESTS AND DISEASES OF FOREST PLANTATION TREES, an annotated list of the principal species occurring in the British Commonwealth, p. 587-588. Clarendon Press, Oxford.
Distribution.

23. Bryan, W. C. 1958. DEFECT IN PIEDMONT HARDWOODS. USDA For. Serv., Southeast. For. Exp. Stn. Res. Notes 115, 2 p.
From 55 to 76 percent of oaks sampled had defects caused by borers. The percent of incidence of borer-damaged trees on various sites was as follows: ridge 26, slope 40, cove 32, and lowland or bottom 32.

24. Bryan, W. C. 1960. LOSSES FROM DEFECT IN PIEDMONT HARDWOODS. USDA For. Serv., Southeast. For. Exp. Stn., Stn. Pap. 109, 31 p.
Exclusive of growth defects, the most common source of hardwood defect was insect borers. Losses from insect-caused defects were least in cove sites, in stands of high basal area, and in trees of high vigor.

25. Burke, H. E. 1921. NOTES ON THE CARPENTERWORM (PRIONOXYSTUS ROBINIAE PECK) AND A NEW METHOD OF CONTROL. J. Econ. Entomol. 14: 369-372.
The carpenterworm is one of the worst pests of native live oak (Quercus agrifolia) *and introduced elm* (Ulmus campestres) *in California. For protection, placing a "knock down" screen cage around the trunk of shade trees from May through July is suggested.*

26. Burns, D. P. 1971. INSECTS THAT HURT THE BOURBON STAVE INDUSTRY. Wooden Barrel 38(6): 6-9, 12, 13.
Insect damage in white oak caused the rejection of 1.3-11.4 percent of the staves and stave blanks cut at three mills in Ohio. Grubs were most detrimental to logs of small diameter.

27. Chamberlin, W. J. 1953. INSECTS AFFECTING FOREST PRODUCTS AND OTHER MATERIALS, p. 29-31. Coop. Assoc. Rep., Oregon State Coll., Corvallis.
Systematics, description.

28. Chapman, J. W. 1911. THE LEOPARD MOTH AND OTHER INSECTS INJURIOUS TO SHADE TREES IN THE VICINITY OF BOSTON, p. 41. Bussey Inst., Harvard Univ., Contrib. Entomol. Lab.
Habits of carpenter moth and leopard moth are compared.

29. Chellmann, C. W. 1971. INSECTS, DISEASES AND OTHER PROBLEMS OF FLORIDA'S TREES, p. 27-29. Fla. Dep. Agric. Bull. 196.
The carpenterworm is not considered a serious forest pest in Florida. Habits, signs of attack, control.

30. Childs, L. 1914. OAK PESTS—THE CARPENTERWORM. Mon. Bull. Calif. State Comm. Hort. 3: 259-264.
California live oaks, poplars, willows, locusts, and elms are badly damaged. The adult is known in many places as the goat moth, so named because of its odor. Life history, distribution, and control.

31. Chu, H. F. 1949. HOW TO KNOW THE IMMATURE INSECTS, p. 156. Wm. C. Brown Co., Dubuque, Iowa.
Pictorial key.

32. Comstock, J. H. 1966. AN INTRODUCTION TO ENTOMOLOGY, p. 601-604. Comstock Pub. Associates, N.Y.
Biology, damage, distribution, systematics.

33. Comstock, J. H., Comstock, A. B., and Herrick, G. W. 1938. A MANUAL FOR THE STUDY OF INSECTS, p. 194, 196-197. Comstock Publ. Co., Ithaca, N. Y.
Description.

34. Cotton, E. C. 1906. THE LOCUST TREE CARPENTER-MOTH (PRIONOXYSTUS ROBINIAE PECK), p. 12-14. Ohio Nurs. Orch. Suppl. Bull. 7.
Much of the damage attributed to the locust borer is actually that of the carpenterworm.

35. Craighead, F. C. 1950. INSECT ENEMIES OF EASTERN FORESTS, p. 366, 497-502. USDA Misc. Pub. 657.
Biology, damage, key, control.

36. Dean, G. A. 1920. INSECT ENEMIES OF SHADE TREES AND ORNAMENTALS. *In* Kans. Hort. Soc. Bien. Rep. 35: 159-160.
Life history, control.

37. Doane, R. W. 1912. SOME INSECT PESTS OF CALIFORNIA LIVE OAKS. J. Econ. Entomol. 5: 346-348.
Introduction of carbon bisulphide into the galleries controlled the larvae.

38. Doane, R. W., Van Dyke, E. C., Chamberlin, W. J., and Burke, H. E. 1936. Forest Insects, p. 319-329. McGraw-Hill, N.Y.
Biology, damage, distribution.

39. Dolphin, R. E., Mouzin, T. E., and Cleveland, M. L. 1972. INSECTS ASSOCIATED WITH PEACH WOOD IN EASTERN UNITED STATES. Can. Entomol. 104: 1593-1608.
Host.

40. Donley, D. E., Hay, C. J., and Burns, D. P. 1969. BORERS IN OHIO OAKS. Ohio Woodlands 7: 17-18.
Causes degrade in both red and white oaks. Galleries start at a wound or an old borer gallery. They may be 1 inch in diameter and are always stained dark brown or black.

41. Doten, S. B. 1900. THE CARPENTERWORM. Nev. Agric. Exp. Stn. Bull. 49, 13 p.
A native of this country and very common in willow and wild cottonwoods in Nevada. Information on the appearance of the insect, recognition of damage, biology, and control. Woodpeckers devour the larvae.

42. Duncan, C. D., and Pickwell, G. 1939. THE WORLD OF INSECTS, p. 75-76. McGraw-Hill N.Y.
Biology.

3. D'Urban, W. S. M. 1860. A SYSTEMATIC LIST OF LEPIDOPTERA COLLECTED IN THE VICINITY OF MONTREAL. Can. Nat. and Geol. 5 (4) : 247.
Lists Cossus plagiatus *Walker in the family Zeuzeridae. Rare, collected in July.*

4. Dyar, H. G. 1902. LIST OF NORTH AMERICAN LEPIDOPTERA, p. 362-363. U.S. Nat. Mus. Bull. 52.
Lists Prionoxystus robiniae *and a variety* quercus. *Also lists as synonyms* plagiatus *Walker,* crepera *Grote,* reticulatus *Lintner, and* zabolicus *Strecker.*

5. Dyar, H. G. (rev. W. Schaus). 1937. FAMILY: COSSIDAE. MACROLEP. (ed. A. Seitz), p. 1263-1287. A. Kernen, Stuttgart.
Systematics. Includes list of the original descriptions of the American forms of Cossidae.

6. Ebel, B. H. 1967. PIEDMONT HARDWOODS—WHICH DO WOOD BORERS DAMAGE? South. Lumberman 215 (2680) : 113-114.
In a mill-yard study in the Georgia Piedmont, 25 to 47 percent of the log ends of several species of oak showed insect-caused defects that were attributed largely to carpenterworms and cerambycid borers.

7. Ebel, B. H., Merkel, E. P., and Kowal, R. J. 1972. KEY TO DAMAGE OF SOUTHERN FOREST TREES BY INSECTS. For. Farmer 31 (7) : 31-36.
Key to insect damage.

8. Edwards, H. 1891. INGUROMORPHA SLOSSONII HY. EDWARDS. Entomol. News 2: 71-72.
Discusses the synonymy of several cossid species and states that Cossus plagiata *is a synonym of* Prionoxystus robiniae.

9. Ehrmann, G. A. 1893. VARIETY OF PRIONOXYSTUS ROBINIAE. Can. Entomol. 25: 257.
P. robiniae *var.* quercus *is based largely on the following description: "The whole of the sub-central inner space of the secondaires (edging on the discoidal cell) in the female is semi-transparent orange, similar to that in the male."*

0. Essig, E. O. 1926. INSECTS OF WESTERN NORTH AMERICA, p. 753-754. MacMillan Co., N.Y.
Biology.

1. Essig, E. O. 1931. A HISTORY OF ENTOMOLOGY, p. 732, 926. MacMillan Co., N.Y.
Hosts.

2. Essig, E. O. 1942. COLLEGE ENTOMOLOGY, p. 444-445. MacMillan Co., N.Y.
Biology.

3. Essig, E. O. 1958. INSECTS AND MITES OF WESTERN NORTH AMERICA, p. 753-754. MacMillan Co., N.Y.
Biology, control.

4. Felt, E. P. 1905. INSECTS AFFECTING PARK AND WOODLAND TREES, p. 79-84. N. Y. State Mus. Mem. 8, vol. 1.
The carpenterworm produces serious deformities and thus renders trees unsightly. Information on early history of the insect, habits, description, distribution, hosts, and remedial measures.

55. Felt, E. P. 1930. MANUAL OF TREE AND SHRUB INSECTS, p. 33-35. MacMillan Co., N.Y.
Biology, damage, control.

56. Felt, E. P. 1942. BORERS OF SHADE AND ORNAMENTAL TREES. Trees 5 (3) : 6, 8.
The carpenterworm, a serious pest on the West Coast, is credited with killing more oaks than any other insect. Practical control consists of either cutting the borers out or injecting an insecticide into the gallery.

57. Felt, E. P., and Rankin, W. H. 1932. INSECTS AND DISEASES OF ORNAMENTAL TREES AND SHRUBS, p. 154-155, 295, 325-326, 359. MacMillan Co., N.Y.
Biology, importance, control.

58. Fenton, F. A. 1939. CONTROL OF SHADE TREE BORERS, p. 22-24. Okla. Agric. Exp. Stn. Circ. 84.
In Oklahoma, the carpenterworm has been recorded only from Payne County, but is probably distributed throughout the eastern half of the State. The insect and its damage are described and control procedures are given.

59. Fernald, H. T. 1942. APPLIED ENTOMOLOGY. p. 231-233. McGraw-Hill, N.Y.
Damage, habits.

60. Filmer, R. S. 1945. WHAT ABOUT BORER CONTROL? Home Gard. 6 (3) : 91-95.
Symptoms, control.

61. Fitch, A. 1859. REPORT ON THE NOXIOUS INSECTS OF THE STATE OF NEW YORK, p. 4-11. Fifth Rep., Trans. N. Y. State Agric. Soc.
The locust cossus, Cossus robiniae, *bores large holes in the solid wood of oaks and other trees, admitting air and moisture and causing their decay. The early systematics are discussed and the common name "locust cossus" is proposed. General information on its biology and control are given.*

62. Forbes, W. T. M. 1923. THE LEPIDOPTERA OF NEW YORK AND NEIGHBORING STATES, p. 516-520. Cornell Univ. Agric. Exp. Stn. Mem. 68.
Systematics.

63. Fowells, H. A. 1965. SILVICS OF FOREST TREES OF THE UNITED STATES, p. 579, 594-595, 601, 613, 617, 624, 630, 639. USDA Agric. Handb. 271.
Hosts.

64. Fox, A. C. 1933. EFFECTS OF THE CARPENTERWORM ON THE ASH TREE. Masters' thesis, N. Dak. Agric. Coll., Fargo, 59 p.
Green ash and several other hosts are damaged. Eggs are laid singly or in masses and hatch in 11-14 days. Birds aid in natural control. Fumigation of the galleries is the most practical control.

65. Fracker, S. B. 1941. THE CLASSIFICATION OF LEPIDOPTEROUS LARVAE, p. 39, 78-79. Contrib. Entomol. Lab. Univ. Ill. 43.
Systematics.

66. Fraser, J. P. 1928. DEFECTS IN TIMBER. Timber Trades J. 104: 87-88, 137.
Defines defects referred to in the grading rule book of the National Hardwood Lumber Association.

67. Frost, S. W. 1942. GENERAL ENTOMOLOGY, p. 218, 381, 385. McGraw-Hill, N.Y.
Tunneling habits.

68. Frost, S. W. 1959. INSECT LIFE AND INSECT NATURAL HISTORY, p. 380-385. Dover Publications, N.Y.
Tunneling habits, frass, damage.

69. Garman, H. 1916. THE LOCUST BORER (CYLLENE ROBINIAE) AND OTHER INSECT ENEMIES OF TH BLACK LOCUST, p. 122-123. Ky. Agric. Exp. Stn. Bull. 200.
Carpenterworms were found in the burrows of the locust borer. Habits are briefly described.

70. Gass, R. D. 1967. INSECT AND DISEASE PESTS OF EASTERN COTTONWOOD IN MISSOURI, p. 10-11. Mo. Dep. Conserv., For. Div. Rep.
There is no satisfactory control for the carpenterworm under plantation conditions.

71. Gass, R. D. 1971. For. Div. Mo. Conserv. Comm. For. Pest Rep. 10, p. 3.
Borers, primarily the carpenterworm and red oak borer, Enaphalodes rufulus, *cause an annual loss of $328,000 in Missouri hardwood timber.*

72. Genaux, C. M., and Kuenzel, J. G. 1939. DEFECTS WHICH REDUCE QUALITY AND YIELD OF OAK-HICKORY STANDS IN SOUTHEASTERN IOWA, p. 437-441. Iowa Agric. Exp. Stn. Res. Bull. 269.
Hosts, importance.

73. Gesell, S. G. 1954. INSECT PESTS OF DECIDUOUS SHADE TREES AND THEIR CONTROL, p. 14-15. Pa. Agric. Ext. Serv. Circ. 427.
Biology, injury, control.

74. Gilbertson, G. I. 1915. A SERIOUS TREE PEST. Dakota Farmer 35: 1048.
The insect is a serious pest of South Dakota's shade trees.

75. Gillette, C. P. 1905. INSECTS OF THE YEAR IN COLORADO, p. 59. USDA Bur. Entomol. Bull. 52.
Importance, hosts.

76. Gillette, C. P., and List, G. M. 1918. NINTH ANNUAL REPORT OF THE STATE ENTOMOLOGIST, p. 13. Colo. Circ. 26.
Predicts that black locust will be destroyed in Denver and Boulder Counties by P. robiniae. *Nurserymen in the infested sections have been forbidden to ship black locust.*

77. Girault, A. A. 1913. FRAGMENTS ON NORTH AMERICAN INSECTS—IV. Entomol. News 24: 195.
An incubation period of 15 days was required for eggs deposited by a female moth captured June 2 at a light in Blacksburg, Virginia.

78. Graham, S. A. 1939. PRINCIPLES OF FOREST ENTOMOLOGY, p. 254-256. McGraw-Hill, N.Y.
Biology, damage, control.

79. Graham, S. A., and Knight, F. B. 1965. PRINCIPLES OF FOREST ENTOMOLOGY, p. 356-357. McGraw-Hill, N.Y.
Biology, damage, distribution.

80. Grote, A. R. 1874. LIST OF THE NORTH AMERICAN PLATYPTERICES, ATTACI, HEMILEUCINI, CERATOCAMPADAE, LACHNEIDES, TEREDINES, AND HEPIALI, WITH NOTES. Proc. Am. Philos. Soc. 14: 256-264.
The insect (type species: Cossus robiniae) *is placed in the genus* Xystus. *The genus name* Xyleutes *of Hubner cannot be used, because it was originally applied to none of these species. Range of the insect includes Canada, eastern and middle U.S., and California.*

81. Grote, A. R. 1882. NEW CHECK LIST OF NORTH AM. MOTHS, p. 21. N.Y. Entomol. Club.
Systematics.

82. Grote, A. R. 1896. NOTE ON PRIONOXYSTUS ROBINIAE. Can. Entomol. 18: 98-99.
Systematics, habits.

83. Hamilton, C. C. 1933. THE CONTROL OF INSECTS BORING IN ORNAMENTAL SHRUBS AND TREES, p. 70. *In* Proc. Ninth Natl. Shade Tree Conf.
Control by injecting a fumigant into the burrows.

84. Hampson, G. F. 1892. THE MOTHS OF INDIA. Vol. I, p. 304. Francis & Taylor, London.
Entry not seen, taken from Munro and Fox (1934). Description.

85. Harris, T. W. 1835. A CATALOGUE OF THE ANIMALS AND PLANTS OF MASSACHUSETTS, p. 71-73. Adams & Adams Publishers, Amherst.
Entry not seen, taken from Lintner (1875). Systematics.

86. Harris, T. W. 1841. INSECTS OF MASSACHUSETTS INJURIOUS TO VEGETATION, p. 294-297. Folsom, Welk, and Turston, Printers to Univ. of Cambridge, Mass.
Biology, description, systematics.

87. Haseman, L. 1936. CONTROLLING BORERS OF FRUIT, FOREST, AND SHADE TREES, p. 21-22. Mo. Agric. Exp. Stn. Bull. 373.
The carpenterworm is one of the largest borers in Missouri's timber, but seems to be less important than the cerambycid borers. Notes on biology and control.

88. Hay, C. J. 1968. FRASS OF SOME WOOD-BORING INSECTS IN LIVING OAK (COLEOPTERA: CERAMBYCIDAE: LEPIDOPTERA: COSSIDAE AND AEGERIIDAE). Ann. Entomol. Soc. Am. 61:255-258.
Hand-lens descriptions of extruded dry frass are given for five species. Excrement pellets of the carpenterworm are brown and cylindrical, reaching a maximum length of about 7 mm. When the pellets attain a length of 4-7 mm in fall or spring, emergence can be expected in May, June, or July.

9. Hay, C. J., and Morris, R. C. 1961. (rev. 1970) CARPENTERWORM. USDA For. Serv., For. Pest Leafl. 64, 8 p.
Hosts, evidence of infestation, description, life history, habits, and natural, preventative, and applied control. The 1970 revision omits the recommended use of DDT and chlordane for control.

0. Hay, C. J., and Wootten, J. F. 1955. INSECT DAMAGE IN HARDWOOD SAWLOGS. USDA For. Serv. Cent. States For. Exp. Stn., Tech. Pap. 148, 14 p.
About 88 percent of the oak logs sampled at 19 sawmills in Kentucky had internal insect damage, and 73 percent of the oak boards showed borer injury. Amount of damage increased with size of the tree. Borer tunnels were more numerous in butt than in upper logs.

1. Herbert, F. B. 1919. INSECT PROBLEMS OF WESTERN SHADE TREES. J. Econ. Entomol. 12: 333-337.
Hosts, injury.

2. Herbert, F. B. 1936. INSECT PESTS OF WESTERN OAKS AND THEIR CONTROL. *In* Proc. Third Western Shade Tree Conf., p. 37-38.
The carpenterworm mines in the heart and sapwood of the trunks and larger limbs of coast live oaks and valley oaks, probably causing the death of more oaks than any other insect.

3. Herrick, G. W. 1935. INSECT ENEMIES OF SHADE TREES, p. 165-167, 188, 280. Comstock Publ. Co., Inc., Ithaca, N. Y.
Hosts.

4. Holland, W. J. 1968. THE MOTH BOOK—A GUIDE TO THE MOTHS OF NORTH AMERICA, p. 375-379. Dover Publications, N. Y.
Description.

5. Hollister, W. O. 1920. DISTRIBUTION OF SHADE TREE INSECTS IN 1919. J. Econ. Entomol. 13: 143-147.
Damage, distribution.

6. Hopkins, A. D. 1894. DEFECTS IN WOOD CAUSED BY INSECTS, p. 289-306. West Va. Agric. Exp. Stn. Bull. 35.
Description, damage.

7. Hopkins, A. D. 1910. INSECT INJURIES TO THE WOOD OF LIVING TREES. USDA Bur. Entomol Circ. 126, 4 p.
Damage.

98. Houser, J. S. 1918. DESTRUCTIVE INSECTS AFFECTING OHIO SHADE AND FOREST TREES, p. 329-330. Ohio Agric. Exp. Stn. Bull. 332.
Life history, habits, damage, hosts, distribution, natural enemies, and control.

99. Howard, L. O., and Chittenden, F. H. 1916. THE LEOPARD MOTH: A DANGEROUS IMPORTED INSECT ENEMY OF SHADE TREES, p. 9. USDA Farmers' Bull. 708.
Includes notes on biology and control of P. robiniae.

100. Hutchings, C. B. 1924. A STUDY OF THE PUPAL CASE OF PRIONOXYSTUS MACMURTREI, p. 63-67. Ont. Entomol. Soc. 54th Ann. Rep.
Generic key to the pupae of Cossidae in North America.

101. Imms, A. D. 1957. A GENERAL TEXTBOOK OF ENTOMOLOGY, p. 518, 543. Methuen & Co., Ltd., N. Y.
Systematics.

102. Jaques, H. E. 1947. HOW TO KNOW THE INSECTS, p. 30. W. C. Brown Co. Publishers, Dubuque, Iowa.
Description.

103. Jaynes, R. A. 1969. HANDBOOK OF NORTH AMERICAN NUT TREES, p. 95. W. F. Humphrey Press, Inc., Geneva, N. Y.
Damage, hosts.

104. Johnson, C. W. 1896. THE OAK CARPENTER WORM OR BORER. *In* Pa. Dep. Agric. Ann. Rep. 7, p. 353-355.
Biology, control.

105. Keen, F. P. 1938. (Rev. 1952) INSECT ENEMIES OF WESTERN FORESTS, p. 198-200. USDA Misc. Pub. 273.
Biology, importance.

106. Kellogg, V. L. 1905. AMERICAN INSECTS, p. 385-386, 594. Henry Holt & Co., N. Y.
Description.

107. Kirby, W. F. 1892. A SYNONYMIC CATALOGUE OF LEPIDOPTERA HETEROCERA: Vol. 1. Sphinges and Bombyces, p. 867. Gurney and Jackson, London.
Entry not seen, taken from Barnes and McDonnough (1911). Synonymy.

108. Kotinsky, J. 1921. INSECTS INJURIOUS TO DECIDUOUS SHADE TREES AND THEIR CONTROL, p. 69-70. USDA Farmers' Bull. 1169.
Although carpenterworms rarely kill trees, they cause unsightly deformities. Information on recognition of the insect, damage, seasonal history, prevention, and control.

109. Kowal, R. J., and Ebel, B. H. 1972. INSECTS ATTACKING FOREST TREES IN THE SOUTH. For. Farmer 31 (7) : 24-30.
Importance.

110. Lauderdale, J. L. V. 1952. INSECT PESTS OF ORNAMENTALS, p. 17-22. Ariz. State Entomol. Rep. 1950/1951.
Habits, hosts, control.

111. Leonard, M. D. 1926. A LIST OF THE INSECTS OF NEW YORK, p. 570. Cornell Univ. Agric. Exp. Stn. Mem. 101.
Distribution.

112. Levison, J. J. 1908. HOW TO EXTERMINATE TREE BORERS. Gard. Chron. Am. 7 (2) : 35-36.
Control.

113. Lintner, J. A. 1875. ON SOME SPECIES OF COSSUS. Rep. N. Y. State Mus. 30: 242-248.
Describes Cossus reticulatus *(a new species),* C. plagiatus *Walker, and* C. crepera *Harris.*

114. Lockard, C. R., Putnam, J. A., and Carpenter, R. D. 1963. GRADE DEFECTS IN HARDWOOD TIMBER AND LOGS. USDA Agr. Handb. 244, 39 p.
Grub holes are grading defects in factory logs because they limit the length of cuttings. They are less important in construction and local-use logs.

115. Lutz, F. E. 1921. FIELD BOOK OF INSECTS, p. 203. G. P. Putnam's Sons, N. Y.
Hosts, systematics.

116. MacAloney, H. J., and Ewan, H. G. 1964. IDENTIFICATION OF HARDWOOD INSECTS BY TYPE OF TREE INJURY, North Central Region, p. 61. USDA For. Serv. Res. Pap. LS-11. Lake States For. Exp. Stn., St. Paul, Minn.
The carpenterworm and its injury to trees are described and hosts are given. The report is designed to help the fieldman without specialized training in entomology to identify the insects causing tree damage.

117. McDaniel, E. I. 1933 (rev. 1936). SOME WOOD BORERS ATTACKING THE TRUNKS AND LIMBS OF DECIDUOUS TREES AND SHRUBS, p. 35-36. Mich. Agric. Exp. Stn. Spec. Bull. 238.
Biology, damage, control.

118. McFarland, N. 1968. A REARING TECHNIQUE FOR SPEEDING UP THE LARVAL STAGES OF SOME ROOT OR STEM BORING LEPIDOPTERA. J. Res. Lepid. 7: 166.
Reared newly hatched carpenterworms to adults on raw potatoes in less than 1 year.

119. McKnight, J. S. 1964. HARDWOOD RESEARCH IN THE SOUTH. J. Soil and Water Conserv. 19 (2) : 77-78.
Research program.

120. McKnight, M. E., and Tagestad, A. D. 1972. MEGACHILE CENTUNCULARIS IN CARPENTERWORM GALLERY. J. Kans. Entomol. Soc. 45: 51-53.
Carpenterworm galleries provide nesting sites for leafcutter bees.

121. Maisenhelder, L. C. 1951. PLANTING AND GROWING COTTONWOOD ON BOTTOMLANDS, p. 20-21. Miss. Agric. Exp. Stn. Bull. 485.
Carpenterworms deform the tree, weaken small stems, and degrade lumber. Infestations are heaviest on poor sites and in the weaker trees of the stand.

122. Maltais, J. B. 1930. MESURATIONS DE LA CAPSULE CRANIENNE DU VER CHARPENTIER, PRIONOXYSTUS ROBINIAE PECK. Nat. Can. 57: 138-145.
Measurement of a large number of larvae yielded a coefficient of 0.88 mm by Dyar's method. A total of 14 molts were calculated from these data.

123. Matheson, R. 1948. ENTOMOLOGY FOR INTRODUCTORY COURSES, p. 286-287. Comstock Publ. Co., Inc., Ithaca, N. Y.
Life history.

124. Metcalf, C. L., and Flint, W. P. 1932. FUNDAMENTALS OF INSECT LIFE, p. 268. McGraw-Hill, N. Y.
Systematics.

125. Metcalf, C. L., Flint, W. P., and Metcalf, R. L. 1962. DESTRUCTIVE AND USEFUL INSECTS, p. 850-851. McGraw-Hill, N. Y.
Biology, damage, control.

126. Miller, W. E. D. 1967. AN ANNOTATED BIBLIOGRAPHY OF SOUTHERN HARDWOODS. N. C. Agr. Exp. Stn. Tech. Bull. 176, 358 p.
Carpenterworm references.

127. Millers, I. 1971. HARDWOOD BORERS. *In* Forrest Insect Conditions in the United States, 1970, p. 39. USDA For. Serv. Wash., D. C.
A study in Missouri revealed that borers of living hardwood trees cause annual losses of nearly $500,000. Sixty percent of the damage was attributed to the carpenterworm.

128. Milligan, R. H. 1970. OVERSEAS WOOD- AND BARK-BORING INSECTS INTERCEPTED AT NEW ZEALAND PORTS, p. 68. For. Res. Inst. N. Z. For. Serv. Tech. Pap. 57.
Distribution.

129. Mills, H. B. 1941. SHELTER BELT INSECTS, p. 19. Mont. State Ext. Dep. Bull. 194.
Biology, hosts, control, importance.

130. Mitchell, R. T., and Zim, H. S. 1964. BUTTERFLIES AND MOTHS—A GUIDE TO THE MORE COMMON AMERICAN SPECIES, p. 147. Golden Press, N. Y.
Biology, damage.

131. Morris, J. G. 1862. *In* Synopsis of the Described Lepidoptera of North America, p. 123-125. Part I. DIURNAL AND CREPUSCULAR LEPIDOPTERA. Smithsonian Misc. Collect., Smithsonian Inst., Wash., D. C.
Description, hosts, range.

132. Morris, R. C. 1955. INSECT PROBLEMS IN SOUTHERN HARDWOOD FORESTS. South. Lumberman 191 (2393) : 136-139.
Life stages of the carpenterworm are illustrated, and a table outlines the type of damage, tree species attacked, and economic importance.

133. Morris, R. C. 1957. HARDWOOD INSECT PROBLEMS IN THE DELTA. *In* Proc. La. State Univ. Sixth Annu. For. Symp., p. 100-103.
Carpenterworms belong to 1 of 2 major groups of trunk-boring insects. Notes on the biology and habits.

134. Morris, R. C. 1957. LUMBER DEFECT—WHAT IS THE INSECTS' SHARE? South. Lumberman 195 (2341) : 26-27.
In oak logs from Mississippi River bottoms, defects caused by carpenterworms and other trunk-boring insects reduced the value of lumber an average of $22 per M BF. Losses averaged $28 per M for overcup oak butt and upper logs, $19 for all Nuttall oak logs, and $18 for all willow oak logs.

135. Morris, R. C. 1959. INSECTS CAUSE DEGRADE IN OZARK OAKS. USDA For. Serv. South. For. Exp. Stn., South. For. Notes 120, p. 2-3.
Potential values of lumber from Ozark red oaks were reduced as much as $19 per M BF by degrade caused from borer attacks on the living trees.

136. Morris, R. C. 1962. CARPENTERWORMS GROW FAST IN MISSISSIPPI. Miss. Farm Res. 25 (4) : 8.
Biology, damage, and control. Shade trees can be protected by spraying the trunks in early June with a residual insecticide.

137. Morris, R. C. 1964. VALUE LOSSES IN SOUTHERN HARDWOOD LUMBER FROM DEGRADE BY INSECTS. USDA For. Serv. Res. Pap. SO-8, 6 p. South. For. Exp. Stn., New Orleans, La.
In mill-scale studies, insect-caused defects in the trunks of living southern oaks resulted in lumber degrade and value loss averaging about $20 per M BF. On this basis, losses would represent a reduction of $60 million in potential value of the 3 billion board feet of oak lumber sawn annually in the South.

138. Morris, R. C. 1965. CONTROLLING INSECT DAMAGE TO SOUTHERN HARDWOOD FORESTS. *In* Proc. La. State Univ. Fourteenth Annu. For. Symp., p. 114-124.
The carpenterworm is the most important pest of oaks in the Midsouth. Insecticides may be used to protect high-value trees during their final growth for veneer logs, especially when drought or other adverse factors make trees susceptible to attack.

139. Morris, R. C. 1970. WHAT ABOUT HARDWOOD INSECTS? *In* Proc. Fifth For. Insect and Dis. Work Conf., p. 197-201. USDA For. Serv., State and Priv. For., Atlanta, Ga.
Importance, research program.

140. Mosher, E. 1969. LEPIDOPTERA PUPAE, p. 28-29, 148. Entomol. Reprint Specialists, East Lansing, Mich.
Description and key.

141. Munns, E. N. 1940. A SELECTED BIBLIOGRAPHY OF NORTH AMERICAN FORESTRY, p. 465-485. USDA Misc. Pub. 364.
References.

142. Munro, J. A. 1931. CARPENTERWORM INJURY TO ASH IN NORTH DAKOTA. J. Econ. Entomol. 24 : 682-685.
The carpenterworm causes serious injury to green ash around Fargo. Includes notes on life habits and control; Arkansas kingbird and the common kingbird are valuable predators.

143. Munro, J. A., and Fox, A. C. 1933. NOTES ON BORERS OF TREES AND SHRUBS. N. and S. Dak. Hortic. 5 (8) : 91-93.
The carpenterworm is a serious borer of ash in North Dakota.

144. Munro, J. A., and Fox, A. C. 1934. CARPENTERWORM BIOLOGY AND CONTROL. N. Dak. Agric. Exp. Stn. Bull. 278, 23 p.
Information on classification, including early descriptions, common names, distribution, and hosts. Detailed review of life history and control.

145. Munro, J. A., and Riddle, H. W. 1930. INSECT PESTS OF TREES AND GARDENS, p. 8. N. Dak. Agric. Exp. Stn., Circ. 42.
Damage and control.

146. Neumoegen, B., and Dyar, H. G. 1894. PRELIMINARY REVISION OF THE BOMBYCIDAE NORTH OF MEXICO. J. N. Y. Entomol. Soc. 2: 160-166.
Systematics.

147. O'Dell, J. H. 1927. INSECT PESTS PREVALENT DURING 1923 AND 1924, p. 61. 15th and 16th Annu. Rep. Ariz. Comm. Agric. and Hortic.
Impact.

148. Osborn, H. 1916. AGRICULTURAL ENTOMOLOGY, p. 210-211. Lea & Febiger, Phila. and N. Y.
Biology, description.

149. Packard, A. S. 1864. SYNOPSIS OF THE BOMBYCIDAE OF THE UNITED STATES. *In* Proc. Am. Entomol. Soc. Phila. III, p. 388-389.
Systematics.

150. Packard, A. S. 1881. INSECTS INJURIOUS TO FOREST AND SHADE TREES, p. 6-12. U.S. Dep. Inter., Entomol. Comm. Bull. 7.
The locust carpenter moth, Xyleutes robiniae *Harris, is common throughout the United States and bores large galleries in the trunks of oaks including pin oak.*

151. Packard, A. S. 1890. INSECTS INJURIOUS TO FOREST AND SHADE TREES, p. 53-58. USDA Fifth Rep. U. S. Entomol. Comm.
From New England southward to Texas, oak lumber and cordwood is commonly honeycombed by the large black burrows of the carpenterworm. Biology, habits, and control.

152. Peck, W. D. 1818. SOME NOTICE OF THE INSECT WHICH DESTROYS THE LOCUST TREE. Mass. Agric. Repos. and J. 5: 67-73.
This is the original description of the carpenterworm. Peck assigns the common name, locust moth, and scientific name, Cossus robiniae.

153. Peirson, H. B. 1927. MANUAL OF FOREST INSECTS, p. 87. Maine For. Serv. (Augusta) Bull. 5.
Hosts.

154. Petch, C. E., and Maltais, J. B. 1932. THE CARPENTER WORM, (PRIONOXYSTUS ROBINIAE) PECK, AND ITS CONTROL, p. 131-136. Que. Agric. Dep., Rep. Que. Soc. Prot. Plants.
Bionomics and control were investigated in an infestation of silver maple at Ste. Anne de Bellevue and St. Laurent, Quebec.

155. Peterson, A. 1962. LARVAE OF INSECTS. I. LEPIDOPTERA AND PLANT INFESTING HYMENOPTERA, p. 132-133. Edwards Brothers, Inc., Ann Arbor, Mich.
Detailed larval description.

156. Peterson, A. 1967. SOME EGGS OF MOTHS FROM SEVERAL FAMILIES OF MICROLEPIDOPTERA. Fla. Entomol. 50: 125-132.
Carpenterworm females deposit eggs singly or in irregular clusters. The egg measures approximately 2.3x1.5 mm. The surface of the chorion is covered with conspicuous irregular indentations.

157. Peterson, L. O. T. 1964. INSECT BORERS IN ASH TREES. Can. Dep. Agric., TN Pam. 2, 10 p.
The carpenterworm is a serious pest of green ash in the prairie region of southeastern Canada. The life cycle is 3 or more years. Moths emerge from early June to early August and deposit 300 or more eggs. Additional information is given on life history and control.

158. Pirone, P. P. 1951. MAINTENANCE OF SHADE AND ORNAMENTAL TREES, p. 255. Oxford Univ. Press, N. Y.
Biology, control.

159. Pirone, P. P., Dodge, B. O., and Rickett, H. W. 1960. DISEASES AND PESTS OF ORNAMENTAL PLANTS, p. 360, 601, 623. Ronald Press Co., N. Y.
Hosts, control.

160. Portman, R. W., and Mannis, H. C. 1958. IDAHO RECOMMENDATIONS FOR INSECT CONTROL, p. 10-11. Idaho Agric. Ext. Serv. Bull. 216.
Description, damage, control.

161. Prentice, R. M. 1965. *In* Forest Lepidoptera of Canada. Vol. 4. Microlepidoptera, p. 740-741. Dep. For. Can. Pub. 1142.
P. robiniae *has been recorded from New Brunswick to interior British Columbia (map shows collection points). Hosts include trembling aspen, black cottonwood, willow, and eastern cottonwood.*

162. Putnam, J. A., Furnival, G. M., and McKnight, J. S. 1960. MANAGEMENT AND INVENTORY OF SOUTHERN HARDWOODS, p. 17-18. USDA Agric. Handb. 181.
Holes, bark pockets, stains, and other blemishes caused by borers and bark scarrers greatly lower the value of hardwoods by limiting the number and size of defect-free pieces that can be cut from lumber.

163. Rivas, A. M. 1964. THE CARPENTERWORM IN MISSOURI. M.S. thesis, Univ. Mo., 76 p.
Life history in Missouri, and economic loss.

164. Rivas, A. M., and Buchanan, W. D. 1958. A NEW TECHNIQUE FOR REARING CARPENTERWORMS. J. Econ. Entomol. 51 (3): 406-407.
Describes an artificial diet, container, and procedures for rearing partially grown larvae.

165. Roberts, E. G. 1956. GRUBS IN THE TRUNKS OF LIVE GREEN ASH TREES. J. For. 54 (12): 846-847.
Discusses grub damage to green ash near State College, Mississippi, and gives measurements of galleries and size of trees infested.

166. Rohwer, S. A. 1916. DESCRIPTIONS OF NEW SPECIES OF HYMENOPTERA. *In* Proc. U. S. Natl. Mus. 49, p. 224-225.
A primary hymenopterous parasite, Amersibia prionoxysti, *of the carpenterworm is described from Falls Church, Virginia.*

167. Ruggles, A. G. 1941. SOME TREE BORING INSECTS. Minn. Hort. 69: 68-69.
Biology, description, control.

168. Schuder, D. L. 1959. TREE BORERS AND EFFECTIVE CONTROL MEASURES. *In* Proc. Natl. Shade Tree Conf., p. 98-104.
Damage and control.

169. Schuder, D. L. 1962. INSECT PESTS OF SHADE TREES AND SHRUBS, A GUIDE FOR COMMERCIAL NURSERYMEN AND ARBORISTS, p. 8-9. Indiana Ext. Serv., Purdue Univ., Mimeo E-41.
Habits, control.

170. Severin, H. C. 1946. INSECT PESTS OF SHELTER BELTS. *In* Agricultural Research in South Dakota, p. 15-16. S. Dak. Agric. Exp. Stn. Fifty-Ninth Annu. Rep.
P. robiniae *is so destructive in the central portion of South Dakota that ash can hardly be grown.*

171. Shenefelt, R. D., and Benjamin, D. M. 1955. INSECTS OF WISCONSIN FORESTS, p. 91-92. Wis. Agric. Exp. Stn. Circ. 500.
Biology, damage, control.

172. Smith, J. B. 1896. ECONOMIC ENTOMOLOGY, p. 286-287. J. B. Lippincott Co., Phila.
Description, damage.

173. Smith, J. B. 1899. INSECTS OF NEW JERSEY, p. 497. MacCrellish & Quigley, State Printers, Trenton, N. J.
Distribution.

174. Smith, R. C. 1943. INSECTS IN KANSAS, p. 214. Kans. State Board Agric. Rep. 62 (255).
Description, control.

175. Snyder, T. E. 1927. DEFECTS IN TIMBER CAUSED BY INSECTS. USDA Bull. 1490, 47 p.
Classifies defects caused by carpenterworms and other insects.

176. Solomon, J. D. 1966. ARTIFICIAL REARING OF THE CARPENTERWORM, PRIONOXYSTUS ROBINIAE (LEPIDOPTERA: COSSIDAE), AND OBSERVATIONS OF ITS DEVELOPMENT. Ann. Entomol. Soc. Am. 59: 1197-1200.
A diet of oak sawdust, agar, water, and nutrients was developed. Adults emerged in 9 to 23 months, with peaks during the 11th and 19th months. Of the larvae, 59 percent pupated, and 88 percent of the pupae produced adults.

177. Solomon, J. D. 1966. TEPA FOR STERILIZING MALE CARPENTERWORMS. J. Econ. Entomol. 59: 1528-1529.
Males were sterilized by topical application of tepa at dosages that neither affected their mating vigor nor reduced their longevity.

178. Solomon, J. D. 1967. CARPENTERWORM OVIPOSITION. J. Econ. Entomol. 60: 309.
Individual females deposited up to 1,000 eggs in bark crevices on the tree trunk. Moths that re-

quired 2 years to develop from egg to adult were more fecund than 1-year moths. Incubation period in the forest was 10 to 11 days.

79. Solomon, J. D. 1967. REARING THE CARPENTERWORM, PRIONOXYSTUS ROBINIAE, IN THE FOREST (LEPIDOPTERA: COSSIDAE). Ann. Entomol. Soc. Am. 60: 283-285.
Eggs were planted in bark wounds and caged on host trees or young larvae were started on an artificial diet and then transferred to drilled holes. Survival averaged about 60 percent in the oaks and about 1/3 less in green ash and American elm.

80. Solomon, J. D. 1967. REGENERATION OF A MANDIBLE IN A LARVA OF THE CARPENTERWORM, PRIONOXYSTUS ROBINIAE, (LEPIDOPTERA: COSSIDAE). Ann. Entomol. Soc. Am. 60: 481-482.
Loss and almost perfect regeneration of a mandible is reported. Mandible losses occurred in laboratory cultures when molting larvae were unduly disturbed by other larvae.

81. Solomon, J. D. 1968. GALLERY CONSTRUCTION BY THE CARPENTERWORM, PRIONOXYSTUS ROBINIAE, IN OVERCUP OAK (LEPIDOPTERA: COSSIDAE). Ann. Entomol. Soc. Am. 61: 72-74.
Larvae began feeding in the cambium area and then tunnelled 3 inches obliquely upward into the sapwood for about 4 months, when they turned vertically upward for 4.3 inches. Gallery diameters averaged 0.6 in.

82. Solomon, J. D. 1969. WOODPECKER PREDATION ON INSECT BORERS IN LIVING HARDWOODS. Ann. Entomol. Soc. Am. 62: 1214-1215.
Fourteen species of insect borers, including the carpenterworm, were preyed upon by woodpeckers in Mississippi.

83. Solomon, J. D. 1971. EMERGENCE AND REPRODUCTIVE STUDIES OF THE CARPENTERWORM MOTH, PRIONOXYSTUS ROBINIAE PECK (LEPIDOPTERA: COSSIDAE). Ph. D. thesis, Miss. State Univ., 101 p.
Moth emergence usually begins in late April, peaks in late May or early June, and ends during late June or early July. Males emerge mostly during the morning, females almost entirely during the afternoon. Mating and oviposition are discussed in detail.

184. Solomon, J. D., Doolittle, R. E., and Beroza, M. 1972. ISOLATION AND ANALYSIS OF THE CARPENTERWORM SEX PHEROMONE. Ann. Entomol. Soc. Am. 65: 1058-1061.
A sex pheromone was extracted from virgin females and bioassay procedures were developed.

185. Solomon, J. D., and Morris, R. C. 1966. SEX ATTRACTION OF THE CARPENTERWORM MOTH. J. Econ. Entomol. 59: 1534-1535.
Five traps baited with virgin females captured an average of 270 males (range 38-666). Females were most attractive during the first 2 days. From 20 to 25 percent of the males marked and released 1/4 to 3/4 miles from female-baited traps were recaptured. Seven percent of those released 1 mile from the traps were recaptured.

186. Solomon, J. D., and Morris, R. C. 1971. WOODPECKERS IN THE ECOLOGY OF SOUTHERN HARDWOOD BORERS. *In* Tall Timbers Conf. on Ecological Animal Control by Habitat Management Proc. 2 (1970), p. 309-315. Tall Timbers Res. Stn., Tallahassee, Fla.
Woodpeckers significantly reduced populations of several insect borers, including carpenterworms. Predation was greatest during January and February. In a rearing program, 1,424 carpenterworm moths or 20 percent of the total were taken by woodpeckers.

187. Solomon, J. D., and Neel, W. W. 1972. EMERGENCE BEHAVIOR AND RHYTHMS IN THE CARPENTERWORM MOTH, PRIONOXYSTUS ROBINIAE (LEPIDOPTERA: COSSIDAE). Ann. Entomol. Soc. Am. 65: 1296-1299.
In west-central Mississippi, moth emergence began in April, peaked in late May or early June, and ended in late June or early July. Temperature summation provided a good prediction of seasonal patterns. Moths emerged earliest from trees of small diameter. Emergence rhythms were related to sex and generation time.

188. Solomon, J. D., Newsome, L., and Darwin, W. N. 1972. CARPENTERWORM MOTHS AND CERAMBYCID HARDWOOD BORERS CAUGHT IN LIGHT TRAPS. J. Ga. Entomol. Soc. 7: 76-79.
A portable, battery-operated light trap placed in hardwood stands of Mississippi captured 10 species of borers. Carpenterworm moths were taken in the greatest numbers, females more frequently than males.

189. Solomon, J. D., and Toole, E. R. 1968. CARPENTERWORM PUPAE TRAPPED IN GALLERIES BY FUNGUS MYSELIUM. J. Econ. Entomol. 61: 880-881.
Pupae were trapped in their galleries by spongy mycelium of wood-decay fungi. Irpex mollis, *a fast-growing white rot fungus, was the principal species.*

190. Solomon, J. D., and Toole, E. R. 1971. STAIN AND DECAY AROUND CARPENTERWORM GALLERIES IN SOUTHERN HARDWOOD TREES. USDA For. Serv. Res. Note SO-120, 4 p. South. For. Exp. Stn., New Orleans, La.
The wood was stained around 60 galleries examined in Nuttall oak, American elm, and green ash. Decay was visible around 20 percent of the galleries, mostly in Nuttall oak.

191. Spalding, P. 1905. A DISEASE OF BLACK OAK CAUSED BY POLYPORUS OBTUSUS BERK. Rep. Mo. Bot. Gard. 16: 109-116.
Sporophores were found growing out of carpenterworm tunnels.

192. Stein, J. D., and Kennedy, P. C. 1972. KEY TO SHELTERBELT INSECTS IN THE NORTHERN GREAT PLAINS. USDA For. Serv. Res.

Pap. RM-85, 153 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.
Description, key.

193. Strecker, H. 1898. *In* New Species of Lepidoptera. LEPIDOPTERA: RHOPALOCERES AND HETEROCERES (INDIGENOUS AND EXOTIC). Supplement No. 1, p. 5. Owen's Steam Book and Job Printing Office, Reading, Pa.
A new species, Cossus zabolicus, *is compared to* C. robiniae. *The markings in* C. robiniae *vary; in two dozen females, the reticulations and striae of the wings in no two are alike.*

194. Swaine, J. M. 1915. SHADE TREE INSECTS IN QUEBEC. *In* 7th Annu. Rep. Que. Soc. Prot. Plants from Insects and Fungi, p. 110-111.
The carpenterworm is a serious enemy of ash, maple, and black locust trees in eastern Canada. Damage is described, and controls given.

195. Thatcher, T. O. 1961. FOREST ENTOMOLOGY, p. 195. Burgess Pub. Co., Minneapolis, Minn.
Biology, damage, control.

196. Tietz, H. M. 1945. THE LEPIDOPTERA OF PENNSYLVANIA, A MANUAL, p. 152-153. Pa. Agric. Exp. Stn., State College.
References to early descriptions, faunal zones, life history, and hosts.

197. Toole, E. R., and Morris, R. C. 1957. INSECT AND DISEASE PROBLEMS IN SOUTHERN HARDWOOD FORESTS. *In* Proc. Soc. Am. For. 1956: 65-67.
Insect defects causing lumber degrade, especially the large grub holes made by carpenterworms, are among the major problems.

198. Von Dalla Torre, K. W. 1923. COSSIDAE. *In* Lepidopterorum Catalogus. Pars 29, ed. Embrik Strand. W. Junk. Berlin W. 15, 63 p.
Lengthy catalog of the genera and species. Many references to the early attempts at classifying P. robiniae.

199. Walker, F. 1856. LIST OF LEPIDOPTERA OF THE BRITISH MUSEUM, p. 1514-1515. Cat. Lepid. Heterocera. British Museum, London.
Description, distribution.

200. Walsh, G. E. 1913. INSECT-RIDDEN TIMBER AND THE LUMBER DEFECTS. Wood Craft 20:36-37.
Borers annually destroy an estimated $200 million worth of timber in the United States. In some cases 40 to 50 percent of the commercial value of the lumber cut from infested trees is lost. Woodpeckers are important predators of borers.

201. Ward, J. C., Horn, R. A., Baltes, R. C., and Bulgrin, E. H. 1972. HONEYCOMB AND RING FAILURE IN BACTERIALLY INFECTED RED OAK LUMBER AFTER KILN DRYING. USDA For. Sev. Res. Pap. FPL-165, 36 p. For. Prod. Lab., Madison, Wis.
Carpenterworms and other borers apparently provide infection courts for bacteria responsible for rancid heartwood. This association contributes to honeycomb and deep surface checking under accelerated kiln drying.

202. Wester, H. V. 1968. OTHER CONTROLS FOR DISEASES AND INSECTS THAT ATTACK TREES AND SHRUBS, p. 41. U. S. Dep. Inter. Natl. Park Serv., Tree Preserv. Bull. 6.
Species of the white oak group are most susceptible to carpenterworm damage. Control by injecting an insecticide into holes.

203. Wollerman, E. H. 1963. BARRENNESS IS TOOL IN BORER CONTROL. South. Lumberman 207 (2585): 119-120.
Discusses the use of chemosterilants and attractants for potential control of the locust borer and carpenterworm.

204. Wolley Dod, F. H. 1906. PRELIMINARY LIST OF THE MACRO-LEPIDOPTERA OF ALBERTA. Can. Entomol. 38: 266.
The carpenterworm was reared from a freshly built cottonwood log building.

205. Wygant, N. D. 1938. THE RELATION OF INSECTS TO SHELTERBELT PLANTATIONS IN THE GREAT PLAINS. J. For. 36: 1011-1018.
Borers are the most serious insect problem in shelterbelt trees. The carpenterworm, one of the principal borers of green ash, causes considerable mortality.

INDEX OF SUBJECTS

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Solomon, J. D., and Hay, C. J.
1974. Annotated bibliography of the carpenterworm, *Prionoxystus robiniae*. South. For. Exp. Stn., New Orleans, La. 13 p. (USDA For. Serv. Gen. Tech. Rep. SO-4)

About 200 references, with subject index.

Additional keywords: Cossidae, hardwood borer.

U. S. Department of Agriculture
Forest Service General Technical Report SO-5

Annotated Guide To Training Aids In Wood Products Protection

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Terry L. Amburgey
Lonnie H. Williams
Raymond H. Beal

Southern Forest Experiment Station
Forest Service
U. S. Department of Agriculture
1974

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Annotated Guide To Training Aids In Wood Products Protection

Terry L. Amburgey, Lonnie H. Williams, and Raymond H. Beal

This paper is an attempt to assemble under one cover a listing of training aids on the large variety of topics related to wood products protection. Foreign references in the English language are given to supplement domestic sources in some areas. Various types of audio and visual materials, literature, and educational courses are grouped by categories. Annotations have been supplied where they seem desirable. Some of the annotations have been borrowed from abstracts prepared by authors or from information prepared by the sources listed at the end of the paper. Sources for the aids are given in brackets, together with the cost where known. Complete addresses of supplying organizations are listed alphabetically at the end of the paper. Books may be obtained by writing the publishers. A few references are out of print. They are listed because of their continuing importance, and can probably be obtained from large libraries.

Although no claim is made for completeness, more than 105 individual references, 15 bibliographies, 16 tape programs, 21 films, 1,050 slides, 8 State or association training programs, and other sources of information are listed. The authors would appreciate being informed of omissions or of additional items that become available. In this manner, future editions will be assured of completeness and accuracy. It should be understood that inclusion or omission of any material does not indicate an endorsement or condemnation of its contents by either the authors or the Forest Service, U. S. Department of Agriculture.

In many of the training aids, recommendations for preventing and controlling the biological deterioration of wood refer to the use of chemicals. Some of the chemicals may no longer be registered or recommended for the uses stated. Before any chemical is applied, its status should be checked with the Cooperative State Extension Service (usually at land-grant universities), the county agent, or the National Pest Control Association. Specific information on preservative treatment is available from the American Wood-Preservers' Association and the American Wood Preservers' Institute.

GENERAL INFORMATION ON WOOD

Slide Courses

WOOD STRUCTURE. Slide-tape, 35 minutes, 114 slides.

Explains in detail the anatomy of wood, how preservatives are retained, and why wood shrinks and swells.

[Oregon State University]

HOW WOOD DRIES. Slide-tape, 30 minutes, 76 slides.

Relationship of fiber walls to the swelling and shrinking of wood, the movement of water through wood, and how moisture changes affect wood.

[Oregon State University]

PENETRATION OF LIQUIDS INTO WOOD. Slide-tape, 20 minutes, 80 slides.

Theoretical aspects of fluid flow as related to the treating process, movement of preservatives through wood, and practical aspects of preservation.

[Oregon State University]

PRESSURE WOOD-PRESERVING PROCESSES. Slide-tape, 24 minutes, 119 slides.

Use of pressure-treated wood, how wood is prepared for treating, and how the treating process works.

[Oregon State University]

WOOD PRESERVATION MINI-COURSE. Slide-tape, 50 minutes, 144 slides.
Condensation of the four sound-slide units listed above. It consists of a brief explanation of the principal concepts of the structure, drying, and pressure treating of wood.
[Oregon State University]

FORESTS GROW HOMES. Slide-tape, 60 slides.
[Western Wood Products Association]

Films

IN PURSUIT OF HAPPINESS. 25 minutes.
[American Plywood Association]

FOREST SERVICE FILMS. USDA Forest Service FS-31 (1973).
About 120 films dealing with diverse aspects of forest trees and wood use may be borrowed or purchased.
[U. S. Department of Agriculture]

Literature

American Forest Institute.
No date CHECKLIST FOR COMMUNICATORS.
Catalogues the many publications, slide presentations, and film strips produced by member associations of the Forest Industry Council.
[American Forest Institute, free]

American Wood Council.
No date A READER'S GUIDE TO WOOD PRODUCTS.
Lists 63 booklets which give advice on how wood can be used in and around a home.
[American Wood Council, free]

American Wood Council.
No date HOUSE-HUNTER'S GUIDE.
Helps prospective home buyers to compare design features and mortgage factors of houses.
[American Wood Council, $0.25]

Anderson, L. O.
1969. LOW-COST WOOD HOMES FOR RURAL AMERICA — CONSTRUCTION MANUAL. USDA Agriculture Handbook 364, 112 p.
Detailed discussion of methods of constructing wood-frame homes. Many illustrations.
[Superintendent of Documents, $1.45]

Anderson, L. O.
1970. WOOD-FRAME HOUSE CONSTRUCTION. USDA Agriculture Handbook 73, 223 p.
Detailed discussion of all aspects of constructing wood-frame structures. Well illustrated.
[Superintendent of Documents, $2.60]

Anderson, L. O.
1972. CONDENSATION PROBLEMS: THEIR PREVENTION AND SOLUTION. USDA Forest Service, Research Paper FPL-132, 36 p.
How to control condensation and minimize moisture problems with vapor barriers and ventilation.
[Forest Products Laboratory, free]

Housing and Urban Development.
1972. WISE HOME BUYING. U. S. Department of Housing and Urban Development, 36 p.
Topics include advantages and disadvantages of new and used homes; defects in design, construction, or maintenance; termites and wood rot. Describes responsibilities of HUD-FHA in regard to structural defects and gives addresses of HUD area offices.
[U. S. Department of Housing and Urban Development, free]

Kass, B. L.
1973. HOME BUYER'S CHECKLIST. National Homebuyers and Homeowners Association, 30 p.
Many details, primarily financial, of home buying or selling. Termite inspections and design defects are mentioned.
[National Homebuyers and Homeowners Association, 1225 19th Street N. W., Washington, D. C. 20036, $1.00]

National Forest Products Association.
No date LUMBER AND WOOD PRODUCTS LITERATURE.
Bibliography of literature and audio-

visual materials available from the member companies of the National Forest Products Association and from other cooperating organizations.
[National Forest Products Association; 6 or less are $0.30 each, more than 6 are $0.20 each]

National Forest Products Association.
No date THE HOUSING ISSUE.
Relates the growth of trees to housing.
[National Forest Products Association, $0.08]

Ponderosa Pine Woodwork.
No date HOW TO SPOT A BETTER HOME.
Includes 16 important factors to consider when looking for a new home or apartment to help get the most for your investment now and avoid pitfalls later.
[Ponderosa Pine Woodwork, free]

Southern Forest Products Association.
No date HOME BUYER'S GUIDE TO VALUE HOMES.
Some of the latest and best ideas on home design and construction.
[Southern Forest Products Association, free]

USDA Forest Products Laboratory.
1973. LIST OF PUBLICATIONS OF INTEREST TO ARCHITECTS, BUILDERS, ENGINEERS, AND RETAIL LUMBERMEN. Forest Products Laboratory Report, 15 p.
Partial listing of literature on use of wood particularly in houses and other light-frame construction.
[Forest Products Laboratory, free]

Tapes

TREES AND ENVIRONMENT CASSETTE SERIES
Seven cassettes, each with a 15-minute program on each side. Side 2 of cassette No. 3 discusses Trees and Housing and side 1 of cassette No. 6 covers Wood and the Home Environment.
[American Forest Institute, $2.00 each with script]

WOOD-DESTROYING FUNGI

Slide Courses

STAINING OF WOOD AND ITS PREVENTION. Slide-tape, 22 minutes, 78 slides.
How attack by fungi can be prevented or controlled.
[Oregon State University]

RECOGNITION, PREVENTION, AND CONTROL OF WOOD DECAY IN BUILDINGS. Slide-script, 157 slides.
Designed as an outline of a self-teaching seminar for house builders or inspectors.
[North Carolina State University]

PREVENTION OF DECAY OF WOOD IN HOMES. Slide-script, 30-40 minutes, 54 slides.
Shortened version of slide course listed above.
[North Carolina State University]

Films

WOOD DECAY BY FUNGI.
Authoritative discussion of the requirements and activities of wood-destroying fungi. Preventive and control measures are also presented.
[State University of New York]

LONGER LIFE FOR WOOD. USDA Production Number 1156-T-70. 1954. 17 minutes.
Discusses the economics of using treated wood in places where decay may occur and describes the value of good construction. Illustrates treating techniques.
[U. S. Department of Agriculture]

Literature

Amburgey, T. L.
1971. ANNOTATED BIBLIOGRAPHY ON PREVENTION AND CONTROL OF DECAY IN WOODEN STRUCTURES (INCLUDING BOATS). Southern Forest Experiment Station, 123 p.
Lists nearly 500 literature.
[Southern Forest Experiment Station, free]

Amburgey, T. L.
1971. HAZARDS OF EARTHFILL CONSTRUCTION. Pest Control 39(8): 34-36.

Discusses the decay hazard of constructing earthfilled porches, flower planters, and patios adjacent to house foundations.
[Southern Forest Experiment Station, free]

Amburgey, T. L.
1972. PREVENTING WOOD DECAY. Pest Control 40(1): 19-20, 22, 39.
Describes the types of wood-inhabiting fungi and gives rules for decay prevention: (1) use properly seasoned wood (2) keep wood dry while in use (3) avoid soil contact with nonpressure treated wood (4) use pressure-treated wood whenever contact with the soil or other sources of moisture cannot be avoided.
[Southern Forest Experiment Station, free]

Amburgey, T. L.
1974. PREVENTION AND CONTROL OF WOOD-INHABITING FUNGI. Pest Control 42 (6): 22-25.
Describes factors influencing growth of fungi and suggests how pest-control operators can prevent or remedy wood-decay problems.
[Southern Forest Experiment Station, free]

Amburgey, T. L., and D. W. French.
1970. PLASTIC SOIL COVERS REDUCE MOISTURE IN HOMES WITHOUT BASEMENTS. Pest Control 38(11): 26-29.
Also published in Forest Products Journal 21(8): 43-44 (1971).
Putting plastic covers over the soil in crawl spaces reduces the moisture content of sub-floor wooden members.
[Southern Forest Experiment Station, free]

Boyce, J. S.
1961. FOREST PATHOLOGY. Ed. 3. McGraw-Hill Book Co., New York. 572 p.
Discusses wood-inhabiting fungi and has two chapters on the deterioration of wood products. Most of the text is concerned with forest trees.

Cartwright, K. St. G., and W. P. K. Findlay.
1958. DECAY OF TIMBER AND ITS PREVENTION. H. M. Stationery Office, London. 332 p.
Authoritative reference on wood decay and the organisms which cause it. Wood preservatives and methods for their application are covered.
[British Information Services]

De Groot, R. C.
1972. A PRACTICAL LOOK AT WOOD DECAY. Economic Botany 26: 85-89.
General discussion about types of decay, sources of moisture in buildings, and preservative treatments.
[Southern Forest Experiment Station, free]

Findlay, W. P. K.
1962. THE PRESERVATION OF TIMBER. A & C Black, Ltd., London. 162 p.
Methods of preservation, preservatives and their evaluation, and the preservation of wood before and after manufacture. Wood-rotting fungi are briefly considered (p. 15-20).

Hartley, C.
1958. EVALUATION OF WOOD DECAY IN EXPERIMENTAL WORK. USDA Forest Products Laboratory Report 2119, 57 p.

Hickin, N. E.
1972. THE DRY ROT PROBLEM. Ed. 2. Hutchinson & Co., London. 115 p.
Designed for the nonbiologist. Discusses what fungi are, how they affect wood, how to identify decay fungi, the difference between ordinary decay fungi and water-conducting decay fungi, and methods used to preserve wood. Hazardous construction practices are illustrated.
[St. Martin's Press, $8.95]

Hunt, G. M., and G. A. Garratt.
1967. WOOD PRESERVATION. Ed. 3. McGraw-Hill Book Co., New York. 433 p.
Discusses wood-deteriorating agents and presents an authoritative and detailed discussion of the many aspects of wood preservation.

Levi, M. P.
1971. IT'S WOOD ROT, NOT TERMITES. N. C. Agricultural Extension Service, Extension Folder 300, 5 p.
Brief account of the organisms causing wood decay, factors that promote their growth, and how attacks on buildings may be prevented.
[North Carolina State University, $0.02 each in lots of 20 or more]

Levi, M. P.
1972. PORIA INCRASSATA OR DRY ROT IN WOOD. N. C. Agricultural Extension Service, Extension Folder 301, 5 p.
Brief discussion of how to recognize, control, and prevent decay by this water-conducting fungus.
[North Carolina State University, $0.02 each in lots of 20 or more]

Nicholas, D. D., Ed.
1972. WOOD DETERIORATION AND ITS PREVENTION BY PRESERVATIVE TREATMENTS. VOL. I. DEGRADATION AND PROTECTION OF WOOD. VOL. II, PRESERVATIVES AND PRESERVATIVE SYSTEMS. Syracuse University Press, Syracuse, N. Y.

Scheffer, T. C., and R. M. Lindgren.
1940. STAINS OF SAPWOOD PRODUCTS AND THEIR CONTROL. USDA Technical Bulletin 714, 124 p.
Authoritative discussion of fungal stains and how they may be prevented and controlled.

Scheffer, T. C., and A. F. Verrall.
1973. PRINCIPLES FOR PROTECTING WOOD BUILDINGS FROM DECAY. USDA Forest Service, Research Paper FPL-190, 56 p.
Discusses problems caused by decay in buildings in the U. S. and the means to avoid or control them. Moisture situations and construction features most responsible for the occurrence of decay in various building parts are described, and directions are given for eliminating undesirable conditions.
[Superintendent of Documents, $1.05]

USDA Forest Products Laboratory.
1971. LIST OF PUBLICATIONS ON WOOD PRESERVATION. USDA Forest Products Laboratory Report, 13 p.
Includes publications that give general information and the results of research by the Forest Products Laboratory on preservative materials, methods of application, and service life of treated and untreated wood.
[Forest Products Laboratory, free]

USDA Forest Service.
1969. WOOD DECAY IN HOUSES: HOW TO PREVENT AND CONTROL IT. USDA Home & Garden Bulletin 73, 17 p.
Seasoned, properly used wood is a dependable building material. In properly designed houses that are well built and well maintained, decay causes little damage.
[Superintendent of Documents, $0.30]

Verrall, A. F.
1968. PORIA INCRASSATA ROT: PREVENTION AND CONTROL IN BUILDINGS. USDA Technical Bulletin 1385, 27 p.
Biology of this water-conducting fungus and how decay may be prevented.
[Southern Forest Experiment Station, free]

WOOD-DESTROYING INSECTS

General Information

Bletchly, J. D.
1967. INSECT AND MARINE BORER DAMAGE TO TIMBER AND WOODWORK RECOGNITION, PREVENTION, ERADICATION. H. M. Stationery Office, London. 88 p.
A well-illustrated aid to the identification of damage not only by major wood-boring pests but also by numerous insects only incidentally occurring in wood.
[British Information Services]

Chamberlin, W. J.
1960. INSECTS AFFECTING FOREST PRODUCTS AND OTHER MATERI-

ALS. Oregon State University Cooperative Association, Corvallis, Ore. 159 p.
Information on beetles and other insects which may occur in wood and wood products from Western States.

Ebeling, W.
1974. URBAN ENTOMOLOGY. University of California, Office of Agricultural Publications (in press).
An authoritative, broadly based reference for every pest control firm and many entomologists. Urban entomology is just being recognized as equal in importance to well-established areas such as forest, agricultural, and medical entomology. Chapters related to wood-products protection include entomological organization and legislation, pesticides and their uses, equipment for pesticide application, and wood-destroying insects and fungi.
[University of California]

National Pest Control Association.
1973. 23-YEAR INDEX OF TECHNICAL RELEASES SELECTED FOR COMPILATION, 1950-1972. National Pest Control Association, 27 p.
Practical information on the biology and control of wood biodeterioration pests as well as all other invertebrate and vertebrate pests in and around structures. Usually a single pest or type of pest is considered in each release.

Sweetman, H. L.
1965. RECOGNITION OF STRUCTURAL PESTS AND THEIR DAMAGE. W. E. Brown Co., Dubuque, Iowa. 371 p.
Comprehensive and especially useful for miscellaneous pests occurring in wood.

Truman, L. C., and W. L. Butts.
1967. SCIENTIFIC GUIDE TO PEST CONTROL OPERATIONS. Ed. 2. Pest Control Magazine, Cleveland, Ohio. 187 p.
Originally produced as a correspondence course in pest control. Wood decay and wood products insects other than termites receive very brief treatment.

Termites

Slides

PREVENTION OF TERMITE ATTACK IN HOUSES. Slide-script, 37 slides.
Biology of subterranean termites and prevention of attack.
[North Carolina State University]

Films

BATTLE OF THE CENTURIES. 1932.
Ant versus termite. The complete life cycle of the common ant, excellently organized pattern of insect existence and struggle.
[Purdue University][1]

BLOCK THAT TERMITE. 1940. 20 minutes.
Habits and habitat of underground termites; methods to protect new buildings from infestation; procedures to prevent further damage after buildings are attacked. Methods of protecting infected buildings and points to be observed in constructing new buildings to prevent termite damage.
[Purdue University]

BUILT-IN TERMITE CONTROL. 1962. 13-1/2 minutes.
Designed to help pest control operators sell soil pretreatment to building contractors and architects.
[Purdue University]

EARTHEN CURTAIN. 1954-1955.
Termite control.
[Purdue University]

FLAGELLATES OF TERMITES. Part 1, American, 48 minutes; Part 2, Australian, 50 minutes; Part 3, 55 minutes.
Shows approximately 100 species, their locomotion and other unusual features which cause biological problems.
[Purdue University, Part 1—$62.00, Part 2—$45.00, Part 3—$49.00]

TERMITE CONTROL. 1949. 22 minutes.
Life history of the termite, damage, and control.
[Purdue University]

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[1] Although many Purdue films are available from one or more sources, Purdue University is given as the source because its film catalogue is a valuable reference in itself.

TERMITES. 23 minutes.
The life cycle, colonization, wood- and earth-dwelling types, preventing damage.
[Purdue University]

TERMITES AND THEIR CONTROL. 1956. 14 minutes.
Illustrates construction errors that allow termite entrance. Discusses kinds of termites, shows how they can be distinguished from ants, and suggests control methods.
[Purdue University]

TERMITES OF THE GOLD COAST. 25 minutes.
Remarkable scenes of egg laying and nests of African species of termites. The species shown are much different from termites found in the U.S.
[Purdue University]

THE INTRUDER. 28 minutes.
About a high school boy who becomes interested in termites when they are discovered in his home. He decides to make termites his project for his school's science fair. Illustrates methods of prevention and treatment of infested homes. Rare scenes of termites, their nests, methods of attack and damage to homes.
[Purdue University]

Literature

Beal, R. H.
1967. FORMOSAN INVADER. Pest Control 35(2):13-17.
A popular article on the discovery of the Formosan subterranean termite (Coptotermes formosanus *Shiraki*) *in the continental United States in 1965. Characteristics by which to recognize this termite are presented as well as a comparison with the native termite* [Reticulitermes flavipes (*Kollar*)].

Beal, R. H., and V. K. Smith.
1972. CARBAMATE OR PHOSPHATE INSECTICIDES FOR SUBTERRANEAN TERMITE CONTROL? Pest Control 40(7): 20, 22, 43.
Phosphate insecticides may have value as a soil treatment.
[Southern Forest Experiment Station, free]

Carter, F. L., C. A. Stringer, and R. H. Beal.
1970. PENETRATION AND PERSISTENCE OF SOIL INSECTICIDES USED FOR TERMITE CONTROL. Pest Control 38(10): 18-20, 22, 24, 62.
A popular article on the penetration and persistence of dieldrin and heptachlor in seven soil types throughout the United States.
[Southern Forest Experiment Station, free]

Ebeling, W.
1968. TERMITES — IDENTIFICATION, BIOLOGY, AND CONTROL OF TERMITES ATTACKING BUILDING. California Agricultural Experiment Station Manual 38, 4 p.
Comprehensive and easily understood. Abundantly illustrated to simplify identification of many U.S. species. About half of the booklet is devoted to control.
[University of California, $1.00]

Ebeling, W., and R. J. Pence.
1965. TERMITE CONTROL — PREVENTION AND CONTROL OF THE WESTERN SUBTERRANEAN TERMITE. California Agricultural Experiment Station Circular 469, 16 p.
A compilation of practical information. Other wood-destroying insects are briefly discussed.
[University of California]

Harris, V. W.
1961. TERMITES: THEIR RECOGNITION AND CONTROL. John Wiley & Sons, Inc., New York. 187 p.
The first account in English of termite damage as a world problem. Comprehensive information not only on damage to buildings but also on part of termites in reducing yield of agricultural crops. Well illustrated.

Hickin, N. E.
1971. TERMITES: A WORLD PROBLEM. Hutchinson & Co., London. 232 p.
Primarily written for the layman. Discusses what termites are and how they affect wood. Brief classification of ter-

mites as well as methods for collecting and preserving specimens. Helpful for beginning termitologists.
[St. Martin's Press, $10.00]

House, P. E.
1970. TERMITES: A STUDY IN SOCIAL BEHAVIOUR. Hutchinson & Co., London. 150 p.
Mainly for the student of entomology.

Johnston, H. R., V. K. Smith, and R. H. Beal.
1971. CHEMICALS FOR SUBTERRANEAN TERMITE CONTROL: RESULTS OF LONG-TERM TESTS. Journal of Economic Entomology 64: 745-748.
[Southern Forest Experiment Station, free]

Johnston, H. R., V. K. Smith, and R. H. Beal.
1972. SUBTERRANEAN TERMITES. THEIR PREVENTION AND CONTROL IN BUILDINGS. USDA Home and Garden Bulletin 64, 30 p.
Detailed, illustrated advice on chemical soil treatments and desirable building practices. A good booklet for homeowners.
[Southern Forest Experiment Station, free]

Kofoid, C. A.
1934. TERMITES AND TERMITE CONTROL. University of California Press. 785 p.
One of the first and most comprehensive books on the biology of termites. Describes the termites of the United States, Mexico, Canal Zone, the West Indies, Hawaii, and the Philippine Islands. Suggests ways of preventing damage by methods of construction and the use of chemically treated and unpalatable woods.

Krishna, K., and F. M. Weesner.
1969-70. BIOLOGY OF TERMITES. 2 vols. Academic Press, New York.
Invaluable for biologists, physiologists, entomologists, and graduate students.

Lee, K. E., and T. G. Wood.
1971. TERMITES AND SOILS. Academic Press, New York. 251 p.
The significance of termites in soil formation and the incorporation of organic matter in the soil is critically examined.

National Pest Control Association.
1973. APPROVED REFERENCE PROCEDURES FOR SUBTERRANEAN TERMITE CONTROL. 168 p.
Comprehensive report on all aspects of control in structures. This is a basic guide for the pest control industry and the public.
[National Pest Control Association. NPCA member price $25.00, nonmember price $75.00]

Smith, V. K., Jr., and H. R. Johnston.
1970. EASTERN SUBTERRANEAN TERMITE. USDA Forest Pest Leaflet 68, 8 p.
Brief description, including habits, evidence of attack, prevention, and control. Written for the general public.
[Southern Forest Experiment Station, free]

Snyder, T. E.
1935. OUR ENEMY THE TERMITE. Comstock Publishing Co., Inc. Ithaca, N. Y. 196 p.
Very complete treatise written by a world authority for the nonprofessional reader.

Snyder, T. E.
1949. CATALOG OF THE TERMITES (Isoptera) OF THE WORLD. Smithsonian Miscellaneous Collection, vol. 112, 490 p.
Taxonomy.

Snyder, T. E.
1954. ORDER ISOPTERA. THE TERMITES OF THE UNITED STATES AND CANADA. National Pest Control Association, N. Y. 64 p.
Taxonomic key. Indicates distribution of termites.

Snyder, T. E.
1956. ANNOTATED SUBJECT HEADING

BIBLIOGRAPHY OF TERMITES 1350 BC TO AD 1954. Smithsonian Miscellaneous Collection, vol. 130, 306 p.

Snyder, T. E.
1961. SUPPLEMENT TO THE ANNOTATED SUBJECT HEADING BIBLIOGRAPHY OF TERMITES 1955 TO 1960. Smithsonian Miscellaneous Collection, vol. 143, No. 3, 137 p.

Snyder, T. E.
1968. SECOND SUPPLEMENT TO THE ANNOTATED SUBJECT HEADING BIBLIOGRAPHY OF TERMITES 1961 TO 1965. Smithsonian Miscellaneous Collection, vol. 152, No. 3, 188 p.

Sperling, R.
1971. PROTECTING BUILDINGS AGAINST TERMITES. PANS (Pest Articles and News Summaries) Section A 13(4): 345-374.
Describes what designers, builders, manufacturers of building materials, and owners can do to prevent damage. Well presented and illustrated.
[Centre for Overseas Pest Research, College House, Wrights Lane, London W 8 5SJ]

Weesner, F. M.
1965. THE TERMITES OF THE UNITED STATES. A HANDBOOK. National Pest Control Association, 71 p.
Most of the information has appeared elsewhere but is brought together under one cover. The four chapters on regional distribution and keys make this book very useful.

Weesner, F. M.
No date TERMITES AND ALL ABOUT THEM. National Pest Control Association Leaflet.
Designed for handout to the general public.

UNESCO
1962. TERMITES IN THE HUMID TROPICS. 259 p.
More than 40 scientific papers and popular lectures given at a symposium held in New Delhi, India. The symposium was divided into 6 sections: systematics and morphology, physiology and development, general biology, ecology, intestinal cellulose-digesting symbionts, and control and termite-proof construction. Many contributions are from authors of international reputation.
[UNESCO]

Beetles

General Information

Hickin, N. E.
1963. THE WOODWORM PROBLEM. Hutchinson & Co., London. 123 p.
Readable treatment of the causes of wood biodeterioration. Emphasizes biology and control of Anobium punctatum *and other anobiid species, but most other wood-boring beetles as well as wood wasps, termites, and marine borers are discussed.*
[St. Martin's Press, $8.95]

Hickin, N. E.
1967. THE CONSERVATION OF BUILDING TIMBERS. Hutchinson & Co., London. 144 p.
Thorough discussion of the geographic incidence, economic importance, and control of wood-boring beetles in Great Britain.

St. George, R. A.
1970. PROTECTING LOG CABINS, RUSTIC WORK, AND UNSEASONED WOOD FROM INJURIOUS INSECTS IN THE EASTERN UNITED STATES. USDA Farmers' Bulletin 2104, 18 p.
Discusses the biology and control of beetles frequently found damaging unseasoned and recently seasoned wood, usually that which is covered with bark. Gives kiln-drying schedule for control of larvae in infested wood.
[Superintendent of Documents, $0.30 each]

Williams, L. H.
1973. RECOGNITION AND CONTROL OF WOOD-DESTROYING BEETLES. Pest Control 41(2): 24, 26, 28.
Various beetle infestations attributed to powder-post beetles by the pest control industry are described making the point that identification is important for the proper selection of control measures.
[Southern Forest Experiment Station, free]

Williams, L. H.
1973. IDENTIFYING WOOD-DESTROYING BEETLES. Pest Control 41(5): 30, 32, 34, 36, 38, 40.
The acronym ALBOW is proposed as an aid to remembering suggested beetle names. The acronym TOW-A-TOP is suggested for remembering differences in typical biological habits of the beetles which can be used to make sufficient identifications for control measure selection.
[Southern Forest Experiment Station, free]

Williams, L. H., and H. R. Johnston.
1972. CONTROLLING WOOD-DESTROYING BEETLES IN BUILDINGS AND FURNITURE. USDA Leaflet 558, 8 p.
Questions frequently asked by homeowners are answered with practical information. Contrasts in beetle and termite habits and current USDA recommendations for beetle control are also given.
[Superintendent of Documents, $0.25 each]

Films

FOREST LEGACY, 1965. 16 minutes, color.
The first half describes the importance of wood and evolution of forests in England. The second half deals with wood-boring beetles.
[Purdue University]

Anobiidae Literature

Acciavatti, R. E.
1972. THE ECOLOGY OF ANOBIIDAE ASSOCIATED WITH NORTHERN HARDWOOD FORESTS IN CENTRAL NEW YORK, WITH SPECIAL REFERENCE TO *PITLINUS RUFICORNIS* SAY. University Microfilms, Ann Arbor, Michigan. 131 p.
The most extensive study of the second most common anobiid species in structures in the Northeast.

French, J. R. J.
1970. REVIEW OF CONTROL MEASURES AGAINST THE COMMON FURNITURE BEETLE, *ANOBIUM PUNCTATUM* (DeGEER). Journal of the Institute of Wood Science 5(2): 29-32.
Draws significant findings from 45 references about the control of this beetle, the major pest of seasoned wood in Australia, England, Europe, and New Zealand.

Linscott, D.
1963. THE SUSCEPTIBILITY OF TIMBER TO ATTACK AND THE PROBABILITY OF AN INFESTATION BY *ANOBIUM PUNCTATUM* (DeGEER). Proceedings, British Wood Preservers' Association Annual Convention. 30 p.
The information is excellently documented under 15 factors that influence beetle attack. A checklist shows 112 hosts.

Moore, H. B.
1968. DEVELOPMENT AND LONGEVITY OF *XYLETINUS PELTATUS* UNDER CONSTANT TEMPERATURES AND HUMIDITIES. Annals of the Entomological Society of America 61: 1158-1164.
Results are limited to those obtained with adults and with larvae up to 6 weeks after egg hatching.

Moore, H. B.
1970. INCUBATION TIME OF EGGS OF *XYLETINUS PELTATUS* (COLEOPTERA: ANOBIIDAE) UNDER CONSTANT TEMPERATURES AND HUMIDITIES. Annals of the Entomological Society of America 63: 617-618.

National Pest Control Association.
1972. ANOBIID POWDER POST BEETLES. Technical Release 21-72, 7 p.
Practical information about the identification, biology, and control.

Simeone, J. B.
1962. SURVEY OF WOOD-FEEDING ANOBIIDAE IN NORTHEASTERN UNITED STATES INCLUDING A STUDY OF TEMPERATURE AND HUMIDITY EFFECTS ON EGG DEVELOPMENT OF *HADROBREGNUS CARINATUS* (SAY). Proceedings, XI International Congress of Entomology, p. 326-335.
Compares incidence of anobiids in structures and in reference collections. Influences of temperature and humidity on the most common species in the Northeast are briefly reported.

Snyder, T. E.
1935. AN INTRODUCED ANOBIID BEETLE DESTRUCTIVE TO HOUSES IN THE SOUTHERN STATES. Proceedings of the Biological Society of Washington 48: 59-60.
Apparently the only reference to Nicobium hirtum *Illiger, probably the second most common anobiid in structures in the Southeast.*

Spink, W. T., H. R. Gross, and L. D. Kirst.
1966. CAN WATER EMULSIONS OF CHLORINATED HYDROCARBON INSECTICIDES CONTROL THE WOOD-BORING BEETLE *XYLETINUS PELTATUS* (HARRIS) IN STRUCTURAL TIMBERS? Pest Control 34: 12-13, 15, 44, 46.
This report has been the basis for the widespread use of water-emulsion formulations for beetle control.

White, R. E.
1962. THE ANOBIIDAE OF OHIO (COLEOPTERA). Bulletin of the Ohio Biological Survey 1(4): 1-58.
Taxonomy

White, R. E.
1971. KEY TO NORTH AMERICAN GENERA OF ANOBIIDAE, WITH PHYLOGENETIC AND SYNONYMIC NOTES (COLEOPTERA). Annals of the Entomological Society of America 64: 179-191.
The latest and most complete key to anobiids.

Williams, L. H.
1973. ANOBIID BEETLES SHOULD BE CONTROLLED. Pest Control 41(6): 18, 20, 22, 38, 40, 42, 44.
Damages occuring in 4 severe infestations of X. peltatus, *the most common species in structures in the Southeast, are described to emphasize that early detection and control are warranted.*
[Southern Forest Experiment Station, free]

Lyctidae Literature

Christian, M. B.
1940. BIOLOGY OF THE POWDER-POST BEETLES, *LYCTUS PLANICOLLIS* LECONTE AND *LYCTUS PARALLELOPIPEDUS* (MELSH.) PART 1. Louisiana Conservation Revue 9(4): 56-69. Part II 10(1): 40-42.

Gerberg, E. J.
1957. A REVISION OF THE NEW WORLD SPECIES OF POWDER-POST BEETLES BELONGING TO THE FAMILY LYCTIDAE. USDA Technical Bulletin 1157, 55 p.
The newest and most complete taxonomic key for the Lyctidae.

National Pest Control Association.
1961. LYCTID POWDER-POST BEETLES—THEIR BIOLOGY AND CONTROL. Technical Release 19-61, 20 p.
A thorough compilation of practical information. An appendix briefly discusses wood identification, growth, and terminology.

Smith, V. K.
1968. LINDANE CONTROLS LYCTUS POWDER-POST BEETLES DURING AIR-DRYING OF ROUGH ASH LUMBER. Journal of Economic Entomology 61: 323-324.

Wright, C. G.
1959. THE INFLUENCE OF SEVERAL ENVIRONMENTAL FACTORS ON THE DEVELOPMENT OF THE SOUTHERN LYCTUS BEETLE, *LYCTUS PLANICOLLIS* LECONTE. Annals of the Entomological Society of America 52: 632-634.

Wright, C. G.
1960. BIOLOGY OF THE SOUTHERN LYCTUS BEETLE, *LYCTUS PLANICOLLIS*. Annals of the Entomological Society of America 53: 285-291.

Bostrichidae Literature

Fisher, W. S.
1950. A REVISION OF THE NORTH AMERICAN SPECIES OF BEETLES BELONGING TO THE FAMILY BOSTRICHIDAE. USDA Miscellaneous Publication 698, 157 p.
Taxonomy.

Woodruff, R. E.
1967. AN ORIENTAL WOOD BORER, *HETEROBOSTRYCHUS AEQUALIS* (WATERHOUSE), RECENTLY ESTABLISHED IN FLORIDA (COLEOPTERA: BOSTRICHIDAE). Entomology Circular 58, 3 p.
[Florida Department of Agriculture, Division of Plant Industry, Gainesville]

Cerambycidae (old house borer) Literature

Although the old house borer has been studied extensively in Europe and Africa, the numerous references will not be listed here.

McIntyre, T., and R. A. St. George.
1972. THE OLD HOUSE BORER. USDA Leaflet 501, 8 p.
Brief description, including habits, evidence of attack, prevention, and control. Written for the general public.
[Superintendent of Documents, $0.25 each]

National Pest Control Association.
1965. OLD HOUSE BORER. Technical Release 11-65, 10 p.
Good compilation of biology and control, in layman's terms.

WOOD-DESTROYING INSECTS AND FUNGI

Slides

PREVENTION OF DECAY AND TERMITE ATTACK IN HOMES. Slide-script.
Discusses wood-inhabiting fungi and termites, with emphasis on prevention and control.
[North Carolina State University]

National Pest Control Association.
A listing of about 160 slides, some of wood-products pests, may be obtained by writing. Slides may be purchased for about $0.65 each.

Southern Forest Insect Work Conference
Mr. W. H. Echols, Secretary-Treasurer
2406 E. Northside Drive
Jackson, Mississippi 39211
A set of 35 slides of wood products insects may be purchased.

Pest Control Operators of California, Inc.
3444 West First Street
Los Angeles, California 90004
Information about the 20 slide sets being produced by this organization may be found in National Pest Control Operators News, January 1972, p. 12-15.

Films

INSPECTION FOR WOOD DESTROYING ORGANISMS. U.S. Navy Training Film MN 8167A. 18 minutes.
Describes the problems faced by the Navy in maintaining its wooden structures. Explains that wood is destroyed by living organisms and shows how to inspect for damage.
[Purdue University or U.S. Navy]

CONTROL OF WOOD DESTROYING ORGANISMS. U.S. Navy Training Film MN 8167B. 22 minutes.
Outlines control methods.
[Purdue University or U. S. Navy]

WOOD PRESERVATION — EFFECTS OF MARINE ORGANISMS. U. S. Navy Training Film 8167C.
Biology of pests that attack waterfront structures. Primary emphasis is given to marine borers, but fungi and insects are also discussed.
[U. S. Navy]

WOOD PRESERVATION — CONTROL OF MARINE ORGANISMS. U. S. Navy Training Film MN 8167D.
Emphasizes the need for thorough periodic inspections and use of pressure-treated wood.
[U. S. Navy]

TREATING WOOD. 1958. 14 minutes.
Emphasizes the need for treating wood that will be exposed to Florida's damp climate. Lists and discusses wood-destroying agents, shows examples of damage, and discusses protective treatments. Includes a tour of a wood-treating plant.
[Purdue University]

THE MOST IN POSTS. 1956. 20 minutes.
Humorous, but with sound advice for farmers, this film describes the attack of termites and wood rot on fence posts and farm structures.
[Purdue University]

Listing of 16 mm films in entomology and related fields.
List includes many subjects other than wood-products protection and is current as of 1972.
[Purdue University, $1.00]

Listing of filmstrips in entomology and related fields.
[Purdue University, $0.50]

Literature

Biesterfeldt, R. C., T. L. Amburgey, and L. H. Williams.
1973. FINDING AND KEEPING A HEALTHY HOUSE. USDA Forest Service General Technical Report SO-1, 20 p.
General discussion for householders. Shows how construction and design, as well as maintenance, can prevent decay by keeping wood dry. Tells how attack by termites and other wood-destroying insects can be prevented and controlled.
[Southern Forest Experiment Station, free]

Blake, E. G.
1953. ENEMIES OF TIMBER: DRY ROT AND THE DEATH-WATCH BEETLE. Chapman and Hall, London. 206 p.
Detailed discussion of Merulius lacrymans, *a water-conducting decay fungus, and the death-watch beetle.*

Findlay, W. P. K.
1953. DRY ROT AND OTHER TIMBER TROUBLES. Hutchinson & Co., London. 269 p.
Detailed discussion of wood deterioration, by both fungi and insects, in living trees and wood products. Methods of preventing and controlling decay in buildings, ships, and other products.

Findlay, W. P. K.
1967. TIMBER PESTS AND DISEASES. Pergamon Press, London. 280 p.
Describes the principal pests and diseases of standing trees and wood in storage and use, their economic significance, and prevention.

Hickin, N. E.
1963. THE INSECT FACTOR IN WOOD DECAY. Hutchinson & Co., London. 336 p.
Reviewed in Pest Control 33(6): 62-64 (1965). Discusses insects, mainly beetles, which attack and destroy structural wood in Britain.
[St. Martin's Press, $8.95]

Oliver, A. C.
1964. TIMBER PESTS AND THEIR CONTROL. Timber Research and Development Association, St. John's Road, Tylers Green, High Wycombe, Bucks, England. 64 p.
An excellently illustrated reference primarily for diagnosing biodeterioration problems and selecting control measures. Fungi growing in or on wood, beetle pests, and marine borers receive more attention than termites or wood preservation.

Scott, G. A.
1968. DETERIORATION AND PRESERVATION OF TIMBER IN BUILDING. Longmans Green & Co., Ltd.,

London. 148 p.
A practical handbook, primarily for builders in Britain, covering deterioration of wooden members by atmospheric conditions, fungal decay, and insect pests; and methods of treatment.

USDA Forest Products Laboratory.
1955. WOOD HANDBOOK. USDA Agriculture Handbook 72, 528 p.
Basic information on wood as a material of construction, with data for its use in design and specification. Sections are devoted to protection from fungi and insects, painting and finishing, and preservation.
Currently out of print but a revision may be available in late 1974.
[Superintendent of Documents]

USDA Forest Products Laboratory.
1972. LIST OF PUBLICATIONS ON FUNGUS AND INSECT DEFECTS IN FOREST PRODUCTS. Forest Products Laboratory Report, 8 p.
[Forest Products Laboratory, free]

PEST CONTROL TRADE PERIODICALS

PEST CONTROL
Harvest Publishing Company
9800 Detroit Avenue
Cleveland, Ohio 44102
Subscription rates: 1 year, $6.00; 2 years, $10.00

NATIONAL PEST CONTROL OPERATORS NEWS
BEE Publishing Corporation
Executive and Editorial Office
Suite 222
4347 Pampas Road
Woodland Hills, California 91364
Subscription rates: 1 year, $6.50; 2 years, $10.00

PEST CONTROL TECHNOLOGY
Somick Publishing Incorporated
P. O. Box 12356
Cincinnati, Ohio 45212
Subscription rates: 1 year, $12.00; 2 years $20.00

EDUCATION AND TRAINING OPPORTUNITIES

Formal training, Campus or correspondence.

A list of universities offering courses in pest control technology may be obtained from the National Pest Control Association.

Short courses and workshops

Nearly every State has one or more 1- to 5-day courses sponsored by universities, regulatory offices, or pest control associations. Date and location are given monthly in industry trade magazines.

Association-sponsored training in pest-control technology

The National Pest Control Association sponsors a Servicemen's Training Program. Information may be obtained from the NPCA. The California Pest Control Association sponsors courses accredited by California State Polytechnic University and administered by Kellogg-West Center for Continuing Education. The Tidewater Pest Control Association sponsors a course at Thomas Nelson Community College, Hampton, Virginia; it consists of 20 once-a-week sessions.

Training sponsored by State Regulatory Offices

Arizona's course is 20 to 24 lessons, given twice a week and rotated between Phoenix, Tucson, and Yuma. Mississippi's initial course was 20 weeks. Weekly meetings were held in various cities throughout the State. A shorter course is now planned.

Other

National Pest Control Association

Membership cost for extension, research, and regulatory personnel is $9.00 per year. This sum entitles member to receive technical releases. For those who wish to receive all information released by the association, the membership fee is $18.00.

Tape cassettes

Tapes on subterranean termites, other wood pests, and household pests are available from Dr. Austin M. Frishman, 30 Miller Road, Farmingdale, New York 11735.

viceman training manuals

Neil A. Maclean Co.
765 Landess Avenue
P. O. Box 319
Milpitas, California 95035

A series of volumes about the life cycle, habits, and habitats of various insects. Color and black and white closeups.

The following volumes are available at $25.00 each:

Volume I	German cockroach
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Volume VIII	Damp wood termite
Volume IX	Carpet beetle
Volume X	Clothes moth
Volume XI	Black widow spider
Volume XII	Fly
Volume XIII	Brown dog tick

ADDRESSES OF SUPPLIERS OF TRAINING AIDS CITED IN THE PRECEDING PAGES

American Forest Institute
1619 Massachusetts Avenue, N.W.
Washington, D.C. 20036
American Plywood Association

To borrow film write:
Modern Talking Picture Service, Inc.
2323 New Hyde Park Road
New Hyde Park, New Jersey 11040

American Wood Council
1619 Massachusetts Avenue, N.W.
Washington, D.C. 20036

American Wood-Preservers' Association
1625 Eye Street, N.W.
Washington, D.C. 20006

American Wood Preservers' Institute
1651 Old Meadow Road
McLean, Va. 22101

British Information Services
Sales Section
845 Third Avenue
New York, N. Y. 10022

Forest Products Laboratory
USDA Forest Service
Information Services
P. O. Box 5130
Madison, Wisconsin 53705

National Forest Products Association
1619 Massachusetts Avenue, N.W.
Washington, D.C. 20036

National Pest Control Association
The Buettner Building
250 W. Jersey Street
Elizabeth, New Jersey 07207

North Carolina State University
Extension Forest Resources
Box 5488
Raleigh, North Carolina 27607

Oregon State University
Slide tape courses are available in reel-to-reel tapes or cassettes and can be either rented or purchased from:
Forest Extension School of Forestry
Oregon State University
Corvallis, Oregon 97331

Ponderosa Pine Woodwork
39 S. LaSalle Street
Chicago, Illinois 60603

Purdue University
Lists of 16-mm films and film strips in entomology and related fields.
Dr. Gary W. Bennett
Assistant Professor of Entomology
Department of Entomology
Purdue University
W. Lafayette, Indiana 47907

St. Martin's Press, Inc.
175 5th Avenue
New York, New York 10010

Southern Forest Experiment Station
USDA Forest Service
701 Loyola Ave., Rm. T-10210
New Orleans, La. 70113

Southern Forest Products Association
P. O. Box 52468
New Orleans, La. 70150

State University of New York
College of Environmental Science and
Forestry
Syracuse, New York 13210

Superintendent of Documents
U. S. Government Printing Office
Washington, D. C. 20402

UNESCO
Place de Fontenoy
Paris—7e
France

U. S. Department of Agriculture
Office of Information
Motion Picture Service
Washington, D. C. 20250

U. S. Dept. of Housing and Urban
Development
Consumer Information
Public Documents
Distribution Center
Pueblo, Colorado 81009

U. S. Navy Training Films

To borrow:
Film Depository
Naval Photographic Center
U. S. Naval Station
Washington, D. C. 20390

To purchase:
National Audiovisual Center
General Services Administration
Suitland, Maryland 20409

Amburgey, Terry L., Williams, Lonnie H., and
Beal, Raymond H.
1974. Annotated guide to training aids in wood products protection. South. For. Exp. Stn., New Orleans, La. 16 p. (USDA For. Serv. Gen. Tech. Rep. SO-5)

Lists publications, bibliographies, tape programs, films, and slides.

Additional keywords: Pest control, wood decay fungi, stain fungi, termites, wood-destroying beetles, wood-inhabiting insects, building design, preservative treatment.

U.S. Department of Agriculture
Forest Service
General Technical Report SO-6

Economic Analysis of Tree Improvement: A Status Report

George F. Dutrow

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Southern Forest Experiment Station
Forest Service
U.S. Department of Agriculture

1974

Dutrow, George F.

1974. Economic analysis of tree improvement: a status report. South. For. Exp. Stn., New Orleans, La. 10 p. (USDA For. Serv. Gen. Tech. Rep. SO-6)

Review of current literature establishes that most authors believe that tree improvement expands production, although some point out drawbacks and alternatives. Both softwood and hardwood improvement programs have been analyzed. The authors used various models, economic assumptions, and standards of measurement, but available data were limited. Future models should attempt to be more eclectic.

Additional keywords: Seed orchards, harvesting, manufacture.

ECONOMIC ANALYSIS OF TREE IMPROVEMENT: A STATUS REPORT

George F. Dutrow

Review of current literature establishes that most authors believe that tree improvement expands production, although some point out drawbacks and alternatives. Both softwood and hardwood improvement programs have been analyzed. The authors used various models, economic assumptions, and standards of measurement, but available data were limited. Future models should attempt to be more eclectic.

Additional keywords: Seed orchards, harvesting, manufacture.

Rising demands for wood products have caused timber growers to seek methods of increasing per-acre yields. Tree improvement programs have been initiated by public and private landowners anxious to raise production efficiency. Because breeding and planting superior trees alters costs and returns, economists have been asked to analyze the financial efficiency of tree improvement.

Emphasizing methodology, this report summarizes several economic analyses of tree improvement programs. Although the authors discussed here have used various models, economic assumptions, and standards of measurement, all studied the benefits and costs of superior trees, and most concluded that the tree improvement programs they evaluated would expand production.

Since tree improvement is relatively new, data availability largely limited the analyses. Any new analyses should encompass improved methodology and account for additional sources of benefits and costs. To encourage future researchers to develop eclectic models, this report will mention issues requiring further research.

The author was formerly Principal Economist, USDA Forest Service, Southern Forest Experiment Station, New Orleans, La.; he is now Principal Economist, Southeastern Forest Experiment Station, Athens, Ga.

Softwood Studies

Economic pressures have caused resource managers to emphasize softwood improvement. Swofford and Smith (1972) evaluated the economic advantages of the tree improvement program for the national forests in the South. The program is designed to convert present stocking to superior pine stands in one saw log rotation. Seven species were evaluated.

Swofford and Smith used a standard cost-return model. By directly estimating the added physical amount or dollar value of wood attributable to improved strains of planting stock and expressing the estimates as percentage gains in output or selling price, they provided a direct measure of the worth of superior planting stock. Future incremental value was discounted and compared to incremental costs incurred to achieve the gain. Thus, the authors considered only costs and returns clearly attributable to tree improvement. The costs included development of plans, land clearing for orchard sites, finding and evaluating superior trees, grafting and outplanting, protecting and managing seed orchards, and progeny testing.

Returns accrued from gains in volume or quality. Volume benefits pertained only to wood increases attributable to genetic improvement. Quality gains ascribed to tree improvement were greater total and merchantable height, earlier and more complete pruning, and straighter boles—all of which would bring higher stumpage prices. Price gains were expressed as increases in current market prices for stumpage and ranged from zero for white or sand pine to 20 percent for slash pine.

The study ranked species and geographical sites by internal rates of return for stands converted to superior stock. The rates equate costs and benefits and indicate value increases directly attributable to improved trees. The time period for establishing the rates extended from tree selection and orchard establishment, through stand conversion, to the end of the first saw log rotation. All benefits and costs were calculated for a 10-acre unit. Internal rates ranged from 14 to 19 percent, averaging 15.2 percent.

Swofford and Smith estimated the macroeconomic implications of their results. The 1971 allowable cut of 761.2 million board feet would increase to 943.9 million, and total pine inventory would be raised from 41,569.3 to 51,579.4 million board feet. Improved trees would increase the yield from national forests in the South by 24 percent.

Porterfield (1973) used goal programming to compute gains from public and private genetic improvement programs for loblolly pine. Because goals are substituted for constraints, this analytic technique is a desirable extension of linear programming. Goal programming is especially valuable for forestry and genetic applications where correlations exist as goals rather than constraints. For example, no firm is likely to reject a tree improvement program simply because a 9- rather than a 10 percent increase in specific gravity is attainable.

In measuring the economic benefits of tree improvement programs, Porterfield reduced the traits considered to volume and specific gravity. He used both to project gains in pulpwood production and volume alone to assess sawtimber gains.

A key variable in Porterfield's investigation was selection intensity and its associated costs. Selection intensity is explained as "a standardized statistic defined as the selection differential divided by the phenotypic standard deviation of the total population." As selection intensity mounts, the selected trait must vary increasingly from the stand mean, and thus costs of locating acceptable trees escalate.

Porterfield constructed matrices predicting genetic response from wild-stand selection, roguing, and progeny testing. Given the selection intensity for a trait and desired percentage improvement, the resultant selection-cost constraint interacts with predicted genetic responses to minimize deviation from the genetic goal while satisfying the expenditure restriction. The technique allows sensitivity analyses for changes in seed yields or different degrees of progeny testing.

With Porterfield's model, profit impacts of various roguing intensities and wild-stand selection intensities are calculable. Goals can be changed, absolutely or relatively, in response to market conditions. Underlying economic criteria for profit and market conditions include a minimum rate of return on investments and a benefit-cost ratio exceeding one.

Although genetic manipulation that reduces volume loss to rust would increase supplies throughout the South, Porterfield acknowledged that fusiform rust infection levels and subsequent loss in volume are difficult to measure. He accepted an established linear relationship between the percentage of infection and the percentage of trees displaying stem galls. He then ascertained the correlation between infected stems and wood volume lost. By these means he estimated that the total volume lost would be 40 percent of the trees with stem infections. Losses ranged from approximately 3 percent on sites lightly infected to 24 percent where infection was heavy. Costs for orchard establishment, progeny testing, and tree selection varied from $4,400 to $8,500 per acre, and internal rates of return extended from 10 to 14 percent.

Greater wild-stand selection efforts and more intense roguing promised even higher returns. Porterfield found that profitability could be maintained if selection expenditures were doubled or tripled; and genetic and economic gains would climb with higher roguing intensity. Roguing intensities as high as 75 percent were significantly more profitable than minimal roguing, and benefit-cost ratios were three times as great.

Analytical results implied that the greatest profit accrued when many clones were selected, grafts were closely spaced, and orchards were later intensively rogued. A portion of the profit increment was imputed to a decline in rust infection, since roguing permitted volume gains up to 25 percent in medium rust areas.

Hart and Ferrie (1972) used investment requirements and expected returns as a model for evaluating a private tree improvement program in the Piedmont. Their linear program determined the forest management practices required to maximize net profit after taxes, and they concluded that genetically improved stock was optimal.

A decrease in specific gravity by genetic manipulation would reduce milling costs by increasing the bursting strength of linerboard. Moreover, genetically improved stock bred for rust resistance would reduce acreage requirements. The mill required 381,486 acres for its wood supply on rust-free land, and 696,355 where infection was prevalent. Improved planting stock lowered the acreage needs on rust-free lands 14 percent. On infected land, resistant stock cut acreage requirements by 56 percent.

In test cases set up for infected and noninfected areas, alternative rates of return varied from 4 to 8 percent. Genetic improvement would increase present net worth by $6 per acre at an alternative rate of 6 percent. The internal rate of return was 17 percent on lands without rust incidence; where genetic improvement lowered the risk of loss in previously infected areas, the rate of return was 21 percent.

Lundgren and King (1965) viewed accelerated growth rates from superior seeds as an apparent increase in site index. The basis for comparison in their model was the increase in total height at age 50 imputed to improved jack pine and red pine planting stock. For alternative rates of return ranging from 4 to 6 percent, they concluded that the gain in site index necessary to offset costs for tree improvement could be readily attained. For example, returns of approximately 6 to 7.5 percent were projected if site indexes of class 55 land could be increased by 2 units for both species.

Davis (1967) employed a cost model to measure the economic potential of tree improvement. Initial costs were capitalized into the future to provide an estimate of the gains necessary to make the program financially self-sufficient.

All seed-orchard costs, including management, were the variable inputs, and were compared with probable benefits from superior trees. Davis first determined the combination of inputs that minimized seed production costs over time. He then compared this cost to the cost of purchasing seed from external sources to establish a net figure. If the superior seeds increased yields of timber at the end of the rotation and the discounted value of this yield surpassed the net cost of the seed, the investment in a seed-orchard was judged economically sound.

In applying the model, Davis found that with net costs for superior seeds of approximately $10 per pound, an increase of only 1 cord at rotation, or its value equivalent in quality increase, was required. On a 30-year rotation with planted loblolly pine, a 1-cord gain in the crop will provide an increase of 2½ to 4 percent more than from ordinary seed. Davis suggested that such gains were virtual certainties.

Theoretically, the long-run market price of improved seed would cover all costs. Yet, if net costs of producing seeds internally increased, gains needed to justify production would mount. Publicly subsidized or cooperative seed orchards would provide seeds at less than market prices, and net costs of internal production of superior seeds would be significantly higher, as would break-even demands on yield increases. Higher internal seed costs, less expensive external sources, and pressure to increase growth rates on less acreage would generate spiraling future demands for low-cost seed from cooperative and public agencies.

Perry and Wang (1958) found that genetic improvements of yields by a mere 1 or 2 percent could justify seed orchards. Their data indicated that a 2 percent increase in yield with a 25 year rotation would offset seed expenditures of $19 per pound.

Carlisle and Teich (1971), working with white spruce in Canada, asserted that gains of 2 to 5 percent in timber volume would readily offset the costs of furnishing genetically superior seed. Their inputs included several site index classes, five tree spacings, growth increments to the standing crop, an interest and inflation rate, a pulpwood stumpage value, establishment and management costs, and a range of improved yields resulting from superior genotypes. Economic outputs included estimates of rotation age, of profits-or-losses at rotation, and of changes in present net worth from tree improvement, in addition to internal rates of return.

The economic rotation was the age where the cost of waiting another year equalled the expected value growth. Rotation age ranged from 38 to 42 years for pulpwood. Profits rose from $8.42 per acre to $21.17 according to spacing and site index. With spacing fixed, profit increased with site index. Conversely, with site class fixed, profits increased with closer spacing. A 15 percent gain in yield would increase present net worth to a high of $11.91 per acre with additional seed costs of only $0.43 per acre. On the best sites, internal rates of return varied from 6.3 to 6.9 percent.

Similar profitability was sustained when per-acre figures were expanded to an annual planting program of 100,000 acres. An initial investment of $1,500,000 in tree improvement, including 6 percent interest, and an annual expenditure of $23,000 for seed production and collection would generate potential economic benefits of $832,000 per year over a 15-year period.

Hardwood Studies

Hardwood tree improvement efforts have lagged behind softwood programs. Until recently, the demand for hardwoods was easily met with existing supplies, and landowners lacked incentives for undertaking tree improvement programs. Supplies of quality timber are diminishing, however, and forest managers are now expressing interest in growing genetically superior hardwoods.

Marquis (1973) used a cost model in one of the few analyses of hardwood tree improvement. He discussed only species that produce many seeds, grow rapidly, and have high value. Since hardwoods are most frequently regenerated by natural means, a hardwood tree improvement program would not only have to absorb the costs of providing superior stock but would also have to bear the cost of converting to artificial regeneration. The slight demand for quality hardwoods limits the feasible size of seed orchards, and small orchards lack economies of scale. All of these factors limit the size of hardwood tree improvement programs. Marquis assumed that the number of acres seeded or planted each year would not exceed the number required to produce one-third of the annual cut of desirable species. Orchard acreage requirements were 6 acres for paper birch, 8 for black cherry, and 240 for red oak. Development costs were virtually independent of orchard size and thereby imposed a heavy burden on small orchards.

Marquis estimated yields required to justify improvement expenditures. He included all costs up to the time superior seeds were available. In addition, he treated the orchard as a capital asset depreciated over a 25-year period. Depreciation, operating, and harvesting costs determined gross cost per pound of seed. Direct seeding or planting costs for a total program ranged from $25 to $66 per acre, depending on species, orchard size, and seeding requirements.

Hardwood profitability was sensitive to species and intensity of management. In terms of quality or growth rate, black cherry and paper birch required genetic improvements of only about 10 percent. Red oak, on the other hand, would require significantly greater genetic gains to justify the costs of a tree improvement program.

Marquis emphasized the need for intensive management of genetically improved hardwood forests. Planting improved stock without thinning incurs financial loss, and highest profits are realized only when tree improvement and intensive management are combined.

A slightly different approach is Smith's (1973) study of the economics of hardwood plantations. Here the units of analysis were trees cultivated under the superior growing conditions of plantations. Smith collected data from more than 70 sycamore, yellow poplar, and sweetgum plantations and constructed yield equations. He determined that pulpwood prices from $9 to $12 per cord would justify establishment of plantations. Average costs of $100 per acre and rotation lengths between 12 and 16 years were assumed. Smith considered his conclusions unduly conservative because sampled plantations had low quality seedlings and poor cultivation. Both increased yields and reduced costs would lower the prices needed to justify planting hardwoods.

Discussion

The authors surveyed thus far consistently predicted favorable results from tree improvement, and some pointed to advantages accruing from phases other than timber production. Uniformity of tree size and growth rate from improved trees would increase harvesting efficiency. Mill processing operations would derive advantages from uniform tree size, wood fiber lengths, and springwood-summerwood ratios. Thus in vertically integrated firms, improved trees could produce savings in harvesting, transportation, conversion to lumber or pulp, and manufacture of consumer goods. These profits could offset any losses incurred in the tree improvement phase of production (Carlisle and Teich 1971).

Another spillover benefit from improved trees would be the single-expense, multiple-benefit characteristic. Actual costs of establishing a tree improvement program were condensed to a short time span relative to the extension of benefits to a number of future generations. Improved trees also permitted shorter rotations which allowed for reduced capital carrying costs, quicker application of research results, and more frequent opportunities to change land use (Bentley 1973).

Some authors pointed out disadvantages of genetic improvement programs, and others suggested alternative means of increasing production. Bentley (1973) presented negative factors to consider in large scale tree improvement efforts. Any narrowing of gene pools, such as manipulation for superior yields, might increase the susceptibility of trees to pathogen or insect attack. The costs of treating these conditions might not be initially discernible, but could become substantial or even prohibitive. Another possible disadvantage might result from conversion to monoculture. Widespread use of fertilizers or chemical control agents to establish and maintain plantations might create ecological imbalances that would later demand a high corrective price. Another consideration —somewhat difficult to measure—was public opinion, since many people may prefer natural forests to intensively managed ones. Bentley suggested that medium-intensity silviculture might produce forests with desired positive externalities rather than negative ones. Such a forest would minimize the probability of future ecological disaster.

Dawson and Pitcher (1970) suggested techniques that can reinforce genetic improvement programs. They recommended timber-stand improvement as the most promising method of upgrading production in the immediate future and suggested that improvements in protection, utilization, and technology would also increase yields. They predicted high potential gains from matching species to site and cited a study that showed gains as high as 60 percent. These alternatives would not exclude or supplant tree improvement but would increase timber supplies.

Research Goals

Data available to the authors limited their methodologies and restricted the analyses. New analyses should adopt progressively more eclectic models.

Economic analysis of tree improvement must provide inclusive lists of costs and benefits. For example, cost accountability must include future expenditures such as pollution abatement efforts as well as initial expenditure for basic research and development of superior trees. For high-valued hardwoods, data may be required to alter the basis of analysis from the acre to the tree. Future models should include benefits such as decreased costs in harvesting, transportation, and processing.

Methodology will continue to be affected by such controversial items as investment criteria and how to price future goods. Literature in the field of capital theory offers numerous investment criteria. While many authorities agree to the maximum present net worth criterion, strong disagreement persists over the choice of prices, interest rates, and selection of alternatives.

Row (1973) advocated equivalent annual income, a variant of present net worth. This method is especially applicable where investments in tree improvement and forestry must be compared to alternatives that bring annual returns. Equivalent annual income combined with more accurate estimates of uncertainty would clarify managerial decisions. If economic models would include comprehensive estimates of costs and benefits, the chances that management would channel resources into optimal land-use patterns would improve.

Buongiorno and Teeguarden (1973) stressed the benefits of using present net worth as an allocative tool. This measure would allow decision makers to focus on one representative commodity rather than attempt to elaborate the effects of innumerable relative prices. The commodity can be labeled forest consumption and its price—the interest rate. In the analysis, society's propensity to substitute future for current consumption was regarded as an interest rate. Theoretically, this interest rate implied maximum social satisfaction with consumption of forest products, in the present and the future. However, this interest rate must correspond with maximized present net worth. Present net worth is the net value of all current and future costs and revenues. Theoretically the public-agency decision maker would compare present net worths, derived at society's preferred interest rate, and select the maximum values. In practice, no decision-maker can pinpoint this interest rate, but he can use prevailing interest rates or a range of rates around them to maximize present net worth and pinpoint the optimum alternative.

The economic concept of projected demand, for land use as well as for wood production, can aid in the establishment of research priorities. Once demands are specified, research dollars can be invested where the likelihood of payoff is greatest. Ideally, genetically improved trees, advantageous silvicultural practices, and sites for planting would be available simultaneously. Research should accommodate both genetic and cultural advances.

It seems certain that tree improvement research will be intensified. As land and labor available to forestry become scarce and prices rise, increased per-acre yields will be more profitable. The gap between wood-fiber demands and acreage available to supply those demands can be partially closed by genetically superior trees. Research programs designed to develop improved trees must be oriented to production goals, yet be flexible enough to accommodate changing needs. Most important, research programs must be supported long enough to obtain benefits.

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MDPLOT: A Program for Plotting Multi-Dimensional Data

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MDPLOT: A Program For Plotting Multi-Dimensional Data

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A computer program has been developed by applying D. F. Andrews' method of plotting multi-dimensional data. The program is easy to use, provides plots of both low and high resolution, and accepts large data sets.

Additional keywords: Plotting multivariate data, cluster analysis, discrimination, computer plotting.

Graphic methods allow the data analyst to glean essential information rapidly and forcefully. For example, the simple two-dimensional scatter plot communicates at a glance rough ideas of the mean (centroid) and interpoint distances in a bivariate distribution. In addition, the scatter plot can aid in identifying outliers. Data having three or more dimensions are often encountered, however, and then the resulting large numbers of two-dimensional plots are difficult to relate to one another. Moreover, plotting such data two variables at a time does not effectively give information on distances between points in the multi-dimensional space.

Anderson (1960) and Chernoff (1971) proposed graphic methods, but their techniques also fail to provide information on centroids and interpoint distances. Recently, Andrews (1972) proposed a plotting method that avoids this fault.

Our experience with Andrews' method indicates that it has wide applicability in forest genetics research and possibly in many other biological fields. Practical use requires a high-speed computer. This paper describes a program written in ASA FORTRAN IV and illustrates its use with several examples.

A complete listing of the program, including implementation instructions, is available on request to the authors: Southern Forest Experiment Station, Forest Service, USDA, P. O. Box 2008, Evergreen Station, Gulfport, Miss. 39501. The program was written for the UNIVAC 1108 but should be compatible with most computer installations when only low-resolution plotting with a high-speed line printer is desired. Provision is made for plotting on microfilm with high resolution. As programmed, however, this feature is dependent on a Stromberg-Carlson 4020 with FORTRAN-accessible plotting software. Considerable reprogramming may be required on other machines.

PROCEDURE

Let boldfaced capital letters denote matrices and small boldfaced letters denote column vectors. Transposition is denoted by prime, and the dimensions of a vector or matrix will be given in parentheses upon first occurrence in the text. For example, $\mathbf{a}'$ (lxk) denotes a row vector of k elements, and $\mathbf{A}'$ (kxn) denotes the transpose of $\mathbf{A}$ (nxk).

Consider n individuals, each possessing k traits or characteristics measured on some scale (not necessarily the same scale for each trait). View the k ordered measurements for the i^th^ individual as a multivariate observation vector, $\mathbf{x}_i$(kxl), with k elements. Hence the entire data set, $\mathbf{X}$ (kxn) $= [\ \mathbf{x}_1\ \mathbf{x}_2\ \mathbf{x}_3\ \ldots\ \mathbf{x}_n]$ may be viewed as a cluster of n points in k-dimensional space: each point defines the end of a line segment drawn from the origin.

It is desirable to reduce the dimensionality from k to 2 while preserving as much of the relevant information as possible. In other words, the problem is to define a function, say f, which maps points in k-space into 2-dimensional space, in such a way that important relationships are preserved.

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Two of the functions proposed by Andrews have the following form:

$f(t, \mathbf{x}_i) = \mathbf{x}'_i \mathbf{a}_t$ for $-\pi < t < \pi$

where

$\mathbf{a}'_t = (\sqrt{.5}, \sin(t), \cos(t), \sin(2t), \cos(2t), \ldots)$

or, alternatively

$\mathbf{a}'_t = (\sin(t), \cos(t), \sin(2t), \cos(2t), \ldots)$.

Values of f are plotted for each point $\mathbf{x}_i$ over the range of t. A set of data points will appear as a set of lines drawn across the plot, each line representing a single data point $\mathbf{x}_i$.

These functions have the two very desirable properties of:

1. Preserving means, i. e. the average of two or more points in k-space is proportional to the average of the values of f for these points.
2. Preserving distances, i. e. the distance between two points in k-space is proportional to the difference between values of f for these points.

PROGRAM

The program computes and plots values of f as follows:

Step 1: Enter a single observation, $\mathbf{x}_i$

Step 2: (optional) Transform elements of $\mathbf{x}_i$

Step 3: Compute values of f for this data point $\mathbf{x}_i$ and store as a row in a plotting matrix.

Step 4: Repeat Steps 1 to 3 n times.

Step 5: Pass user-designated rows of plotting matrix to output device.

Some of the general features of the program are:

1. Many forms of data input are allowed.
2. Observation vectors with a maximum of 50 dimensions (= elements) are allowed.
3. An open FORTRAN subroutine (INTRAN) is provided for user-defined transformations of the observation vector. These transformations must be in FORTRAN IV.
4. User-defined labels for each observation vector and each element within the vector are retained for labeling the output.
5. Plotting points are computed with either of the functions.
6. Up to 250 observation vectors are allowed per data set. The user may select up to 25 observation vectors from the total data set to be plotted together. No limits are placed on the number of plots generated by the user from a given data set, and all such plots possess the same scale on both axes.
7. Microfilm and high speed printer plots, or both, are allowed. If high-resolution plotting is desired some effort may be required to adapt the program to local facilities.
8. On user's request the projection matrix

   $\mathbf{A}\ (\mathrm{kxr}) = [\mathbf{a}_1 \vdots\ \mathbf{a}_2 \vdots\ \mathbf{a}_3 \vdots\ \ldots \vdots\ \mathbf{a}_r]$

   is generated for k = 50 and r = 99. These vectors correspond to the linear functions

   $f(t, \mathbf{x}_i) = \mathbf{x}'_i \mathbf{a}_r$

   for 99 values of t equispaced in the interval $-\pi, \pi$. If a user is interested in a particular value of t, he may refer to the table of **A** (pages 22-26) to determine the weights applied to each variable in the linear function that generates the plotting values for that t.

Input Preparation

A complete description of the control cards prefaces the main program listing, pages 5-7. Three typical deck setups are shown on pages 8, 14, and 17. The three decks were executed in one computer run—hence a single microfilm card begins the deck on page 17 and a single END card teminates the run after the deck on page 8.

Example 1.—The data for this example are from Andrews (1972). The input deck is listed on page 8, and the output follows on pages

9-13. There are 15 multivariate observations, each consisting of eight canonical variable means resulting from the discriminant analysis of measurements on the permanent first premolar of 15 "races" of apes and men. Card 1 is the title card, 2-16 are the observation name cards, 17 is the input format (specifying free-field input), and 18-32 contains the observation vectors. Card 33 directs the program to plot the 15 observation vectors on one graph (page 9). The absence of a label card immediately following this plot card directs the program to identify the plot with the label in columns 6-53 of card 1. Card 34 directs the program to plot the first nine observation vectors (page 11), and 35 labels this plot. Similarly, 36 and 37 direct plotting of the last six observation vectors with a new label (page 13).

Example 2.—The data are from a chemotaxonomic study in the genus *Pinus.* The input deck is listed on page 14, and the output follows on pages 15-16. There are 12 multivariate observations, each consisting of seven monoterpene measurements (proportion of volatile content). Card 1 is the title card, 2-13 are the observation name cards, 14-20 are the variable name cards, 21 is the input format (specifying free-field input), and 35 labels this plot.

Example 3.—The data are from a study of resistance to bark beetle *(Dendroctonus frontalis* Zimm.) attack in loblolly pine. Monoterpene composition of 20 trees was related to resistance. The input deck is listed on page 17, and the output follows on pages 18-21. The 20 multivariate observations consist of six monoterpene measurements (proportion of total volatiles) on each tree.

Card 2 is the title card; it specifies that a user-defined transformation is provided, and that the number of variables after transformation will be five. The transformation consists of a re-ordering of the variables after application of bioassay weighting factors. Cards 3-22 are the observation name cards, 23-27 are the variable name cards for the five transformed variables, 28 is the input format (specifying free-field input), and the observation vectors are on 29-48. Card 49 directs plotting of the last 10 observation vectors (page 18).

Card 50 is a second title card, specifying the same transformation on the stored data but directing that the alternate form of the plotting function be used. Card 51 directs the plotting of the last 10 observation vectors under these conditions (page 19).

Card 52 is the third title card specifying a transformation—in this case a different reordering of the weighted terpenes from that produced by the first two title cards.

Card 58 directs plotting the last 10 observation vectors under these conditions (page 20).

Card 59 is the fourth title card, and specifies the same conditions as the third title card, except that the alternate plotting function is to be used. Card 60 directs plotting the last 10 observation vectors under these conditions (page 21).

INTERPRETATION OF OUTPUT

Example 1.—Page plotting is highly useful for viewing small numbers of vectors per plot. On page 11 the first nine vectors are easily followed (a dollar sign indicates an overplot), and the microfilm of these vectors, page 12, adds little to the general picture. When plots contain numerous lines, however, microfilm often aids resolution greatly. Compare pages 9 and 10.

Andrews gives a detailed interpretation of these data. Essentially, two distinct groups are formed by the observation vectors 1-9 (page 11), while the remaining six vectors (page 13) show similarities to both of these groups. The most striking result is the deviation of the vector *Proconsul africanus.* Andrews pointed out the peculiarity of this vector, which is most striking for $t = 1.09$. Reference to the table of **A**, pages 22-26, reveals that the plotting vector, $\mathbf{a}_t$, for $t = 1.09$ and eight variables defines f to be

$$f(1.09,x_i) = (.71)x_{1i} + (.89)\ x_{2i} + (.46)x_{3i} + (.82)\ x_{4i} + (-.57)x_{5i} + (-.13)x_{6i} + (-.99)x_{7i} + (-.94)x_{8i}$$

This particular linear function of the discriminant means results in the strongest separation of the vectors. In the same way, other interesting linear functions may be discovered from the plots.

Example 2.—Because the vectors are numerous, the page plot (page 15) is difficult to follow. On microfilm (page 16) distinct groups can be detected, for example vectors B, F, H, and I. Not only are clusters revealed, but peculiar observations such as vector L are made conspicuous by this plot.

Example 3.—The page plot (page 18) for these data is accurate enough to reveal the deviation of two vectors, I and J; four values of t are particularly interesting. Exactly the same conclusion is reached when the same data are plotted with the alternate function (page 19). The reason is that the two plotting functions have the same properties with respect to preservation of means and distances —only the appearance of the plots is affected. The table of **A** may still be used for the alternate function, but the first row is deleted. For example, under the alternate function with five variables the weights for variables 2-6 from the table are correct for variables 1-5.

A re-ordering of the variables often results in a more appealing plot, especially if the most important variables are entered first. Plots on pages 20-21 illustrate the effect. Again, the conclusions are the same since the plotting method is invariant to ordering of the variables with respect to preservation of means and distances.

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      C      I                         PROGRAM  MDPLOT                            I
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      C      ***********
      C      * PURPOSE *
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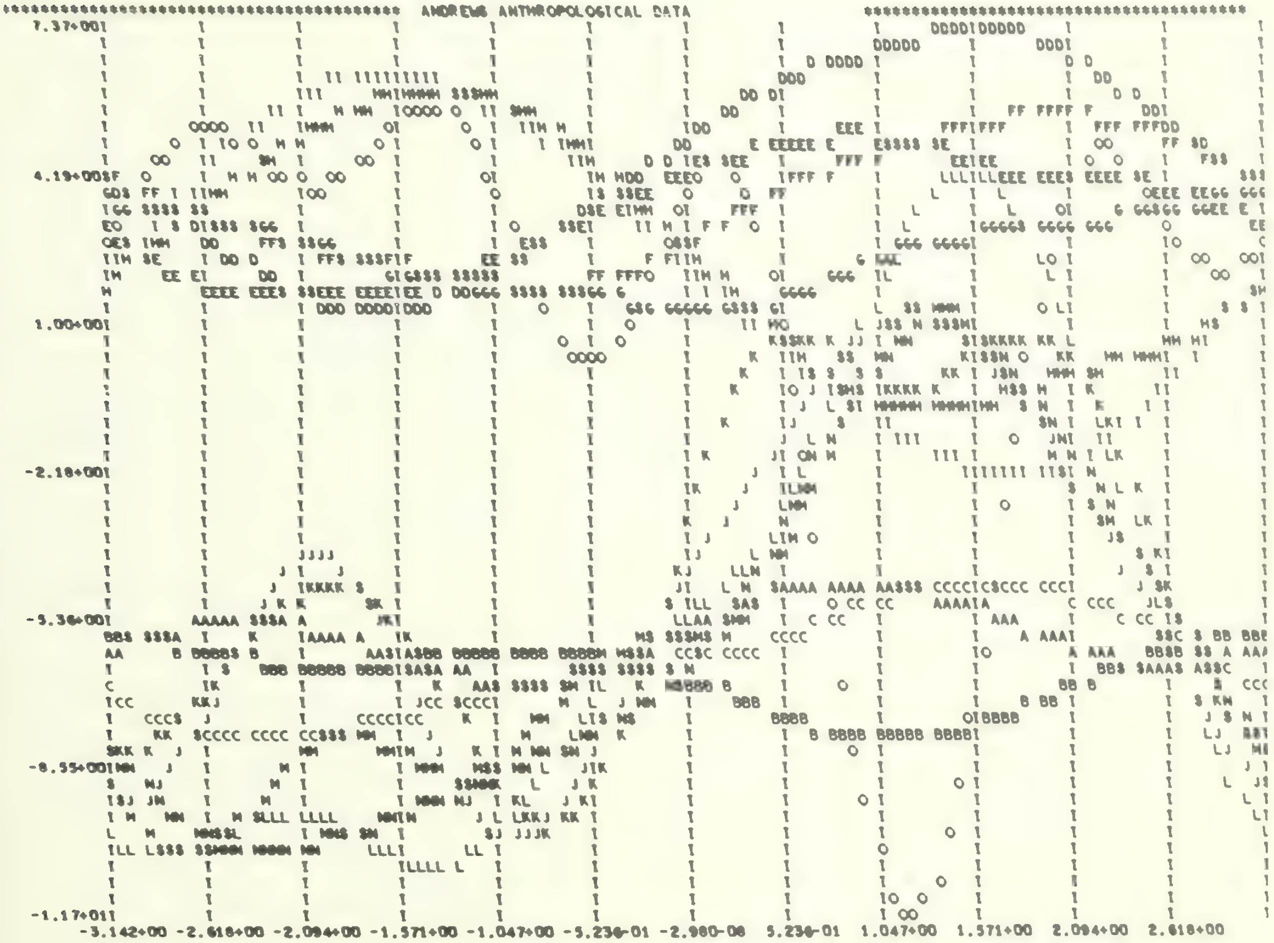
      C          THIS PROGRAM GRAPHICALLY PRODUCES THE ANDREWS" PLOTTING METHOD
      C      **********
      C      * METHOD *
      C      **********
      C          THIS METHOD FOR MULTI-DIMENSIONAL PLOTTING WAS ADAPTED FROM
      C      THE FOLLOWING PAPER.
      C          1972. ANDREWS, D.F.  PLOTS OF HIGH DIMENSIONAL DATA.  BIOMETRICS
      C          28.125 -36.
      C      **************
      C      * CARD ORDER *
      C      **************
      C          MICROFILM CARD
      C          OIS CARDS  (OPTIONAL)
      C          TITLE CARD                                        *****
      C          OBSERVATION NAME CARDS (OPTIONAL AFTER 1ST PROBLEM)    *
      C          VARIABLE NAME CARDS (OPTIONAL)                         *  REPEATED
      C          INPUT FORMAT CARD  (OPTIONAL AFTER 1ST PROBLEM)        *    FOR
      C          DATA CARDS  (OPTIONAL AFTER 1ST PROBLEM)               *    EACH
      C          PLOT CARD              * THIS AND LABEL CARD REPEATED *  DATA SET
      C          LABEL CARD  (OPTIONAL) *FOR EACH PLOT DESIRED     *****
      C          END
      C      ******************          +
      C      * MICROFILM CARD *   INSERTED ONCE FOR EACH SET OF PROBLEMS
      C      ******************
      C          COL. 1  1 IF MICROFILM PLOTTING DESIRED FOR ONE OR MORE
      C                    PROBLEMS IN RUN
      C                  0 IF NOT
      C                    NOTE- THE USE OF MICROFILM IS SC-4020 DEPENDENT.
      C          COL. 2  1 IF TABLE OF LINEAR FUNCTIONS DESIRED
      C                  0 OR BLANK IF NOT
      C      *************
      C      * OIS CARDS *   INSERTED ONCE FOR EACH SET OF PROBLEMS
      C      *************
      C          SHOULD MICROFILM BE DESIRED THIS ENABLES THE CONTROL CLERK TO
      C      RETURN THE DEVELOPED OUTPUT TO THE PROGRAMMER.
      C          CARD 1 COL.  1- 12  USER"S NAME
      C          CARD 2 COL.  1- 12  DESTINATION CODE
      C          CARD 3 COL.  1-  6  PHONE NO.          ,
      C          CARD 4 COL.  1- 48  SOLID ASTERISKS
      C          CARD 5 COL.  1- 54  PROCESSING INFORMATION
      C          CARD 6 COL.  1- 66  SOLID ASTERISKS
      C      **************
      C      * TITLE CARD *    ALWAYS FIRST CARD OF EACH PROBLEM.
      C      **************
      C          COL.  1-  5  THE WORD "TITLE"
      C          COL.  6- 53  ALPHANUMERIC TITLE OF PROBLEM
      C          COL. 54- 56  NO. OF INDIVIDUALS (OR CASES)
      C          COL. 57- 59  NO. OF VARIABLES BEFORE TRANSFORMATIONS
      C          COL. 60- 62  NO. OF VARIABLES AFTER TRANSFORMATIONS
      C          COL. 63- 65  * 1 IF PRINTED PLOTS ONLY DESIRED
      C                      *  2 IF MICROFILM PLOTS ONLY DESIRED  W
      C                       * 3 IF PRINTED PLOTS AND MICROFILM ARE BOTH DESIRED
      C          COL. 66- 68  1 IF TRANSFORMATIONS NECESSARY
      C                       0 IF TRANSFORMATIONS NOT NEEDED
      C          COL. 69- 71  1 IF PREVIOUS DATA INPUT TO BE REREAD
      C                       0 IF NEW SET OF DATA TO BE INPUT
      C          COL. 72- 74  1 IF NEW OBSERVATION NAMES DESIRED AND NO
      C                         VARIABLE NAMES DESIRED
      C                       0 IF USERS PREVIOUS NAMING SYSTEM FOR CHARACTERS
      C                         AND VARIABLES TO BE REREAD
      C                       2 IF NEW OBSERVATION NAMES AND VARIABLE NAMES ARE
      C                         TO BE ENTERED
      C                       3 IF OBSERVATION NAMES ARE TO BE RETAINED BUT
      C                         NEW VARIABLE NAMES ARE TO BE ENTERED
      C          COL. 75- 77  ALTERNATE UNIT NUMBER FOR DATA SET - A ZERO OR
      C                       BLANK DEFAULTS TO SYSTEM STANDARD(UNIT 5)
```

```
C          COL. 78- 80  0 USE THE FOLLOWING STANDARD PLOTTING FUNCTION -
C                           F(T)=SQRT(1/2)X1 + SIN(T)X2 + COS(T)X3 + ...
C                         1 USE FOLLOWING ALTERNATE PLOTTING FUNCTION -
C                           F(T)=SIN(T)X1 + COS(T)X2 + SIN(2T)X3 + ...
C       ****************
C       * OBSERVATION*
C       * NAME CARDS *     REQUIRED IF 1 OR 2 PUNCHED IN COLS. 72-74 OF TITLE CARD
C       ****************   NUMBER OF NAME CARDS (WHEN REQUIRED) MUST EQUAL NO. OF
C                          INDIVIDUALS (OR CASES)
C          COL.  1- 18  NAME OF INDIVIDUAL (OR CASE)
C          REPEAT FOR EACH INDIVIDUAL. NOTE - NAMES SHOULD BE ASSIGNED TO EACH
C          INDIVIDUAL IN SAME ORDER AS INDIVIDUALS ARE TO BE INPUT IN DATA SET,
C          I.E., 2ND NAME WILL BE ATTACHED TO SECOND INDIVIDUAL IN DATA SET.
C       ****************
C       *  VARIABLE  *
C       * NAME CARDS *     REQUIRED IF 2 OR 3 PUNCHED IN COLS. 72-74 OF TITLE CARD
C       ****************   NUMBER OF NAME CARDS (WHEN REQUIRED) MUST EQUAL NO. OF
C                          VARIABLES AFTER TRANSFORMATIONS.
C          COL. 1- 18   NAME OF VARIABLE
C          REPEAT FOR EACH VARIABLE. NOTE - NAMES SHOULD BE ASSIGNED TO EACH
C          VARIABLE IN ORDER AFTER TRANSFORMATION.
C       ******************
C       * INPUT FORMAT *  REQUIRED UNLESS 1 PUNCHED IN COLS. 69-71 OF TITLE CARD.
C       ******************
C          SHOULD PROVIDE FOR F OR E SPECIFICATION FOR EACH VARIABLE BEFORE
C       TRASFORMATION.
C       ****************
C       * DATA CARDS *     REQUIRED UNLESS 1 PUNCHED IN COLS. 69-71 OF TITLE CARD.
C       ****************
C          A MAXIMUM OF 250 INDIVIDUAL CASES, EACH WITH UP TO 50 VARIABLES, MAY
C       BE ENTERED AT ONE TIME.  ALL CARDS FOR EACH INDIVIDUAL SHOULD BE ENTERED
C       IN DATA DECK IN SAME RELATIVE POSITION AS THE CORRESPONDING NAME CARD IN
C       THE NAME CARD SET.
C       ****************
C       * PLOT CARDS *
C       ****************
C          USER MAY CHOOSE FROM TWO TYPES.
C       TYPE 1  USED FOR PLOTTING UP TO 25 CONSECUTIVE CASES IN ONE PLOT
C           COL.  1-  4  THE WORD "PLOT"
C           COL.  5-  6  BLANKS
C           COL.  7-  9  INTEGER NO. SPECIFYING THE RELATIVE POSITION (WITH
C                        RESPECT TO DATA DECK) OF THE FIRST INDIVIDUAL IN SUBSET
C                        TO BE PLOTTED
C           COL. 10      COMMA
C           COL. 11- 13  INTEGER NO. SPECIFYING THE RELATIVE POSITION OF THE
C                        LAST INDIVIDUAL IN SUBSET TO BE PLOTTED
C                        EXAMPLE-  PLOT   10, 25
C                        NOTE-  MAXIMUM NO. OF CASES IN EACH SUBSET CANNOT
C                               EXCEED 25
C       TYPE 2  USED FOR PLOTTING UP TO 25 CASES LISTED INDIVIDUALLY
C           COL.  1-  4  THE WORD "PLOT"
C           COL.  5      BLANK
C           COL.  6-  8  INTEGER NO. OF CASE TO BE PLOTTED
C           COL.  9- 11  INTEGER NO. OF CASE TO BE PLOTTED
C           COL. 12- 14  ETC.
C                        MAXIMUM OF 25 CASES LISTED IN ANY ORDER
C                        EXAMPLE-  PLOT  20  1 14  9 65
C       *****************
C       * LABEL CARDS *  OPTIONAL-  IF NO LABEL CARD IS GIVEN, THE TITLE WILL BE
C       *****************           THE SAME AS COLS. 6-53 ON TITLE CARD.
C           COL.  1-  5  THE WORD "LABEL"
C           COL.  6-53  TITLE FOR THE PLOT PRODUCED BY PRECEEDING PLOT CARD
C       **********************
C       * SUBROUTINES CALLED *
C       **********************
C           OIS
C           READIN
C           CALC
C           ROWF
C
C
C      MAIN
C          (
       INTEGER TLTC, TLTCK, ANAM, END
       DIMENSION A(80),TITLE(12),FMT(18),ANAM(250,5),X(50),F(250,99),IA(8
     10),IVAR(50,5)
      COMMON R(10),IIU,IOU,IALT,IRR
      DATA TLTCK,END/4HTITL,4HEND /
      DATA ITEST/4H****/
      IALT=4
      IPROB=0
      IIU=5
      IOU=6
      IRR=9
      READ(IIU,1)MIC,ITAB
    1 FORMAT(2I1)
      IF (MIC .EQ. 0 ) GO TO 4999
C     THE FOLLOWING SUBROUTINE IS MICROFILM DEPENDENT
      CALL OIS
 4999 READ (IIU,10) TLTC,TITLE,NCS,NXVB,NXVA,IPRINT,ITRAN,IREAD,NEWCH,
     1IUNIT,ISIN
   10 FORMAT(A4,1X,12A4,9I3)
      WRITE(IRR,10) TLTC,TITLE,NCS,NXVB,NXVA,IPRINT,ITRAN,IREAD,NEWCH,
     1IUNIT,ISIN
 5000 BACKSPACE  IRR
      READ(IRR,10)  TLTC,TITLE,NCS,NXVB,NXVA,IPRINT,ITRAN,IREAD,NEWCH,
     1IUNIT,ISIN
      IPROB = IPROB + 1
      IF (TLTC .EQ. TLTCK) GO TO 99
      BACKSPACE IRR
      READ(IRR,30)  (A(J),J=1,80)                                         1
   30 FORMAT(80A1)
      WRITE(IOU,40)  (A(J),J=1,80)                                        1
   40 FORMAT(78H1THE FOLLOWING CARD IS NOT LABELED "TITLE". PROGRAM IS E
     1XPECTING A TITLE CARD. / 1H0, 80A1)
 8000 READ(IIU,42) IA
   42 FORMAT(80A1)
      WRITE(IRR,42) IA
      BACKSPACE IRR
      READ(IRR,43) NXTLE
   43 FORMAT(A4)   "
      IF(NXTLE.EQ.TLTCK) GO TO 5000
      IF(NXTLE.EQ.END) STOP
      GO TO 8000
   99 IF(NEWCH.EQ.0.OR.NEWCH.EQ.3) GO TO 161
      READ(IIU,60)((ANAM(I,J),J=1,5),I=1,NCS)
   60 FORMAT(5A4)
      IF(NEWCH.EQ.1) GO TO 163
  161 IF(NEWCH.EQ.0) GO TO 65
      READ(IIU,60)((IVAR(I,J),J=1,5),I=1,NXVA)
      GO TO 65
  163 IVAR(1,1) = ITEST
   65 IF (IREAD .EQ. 1) GO TO 90
      READ(IIU,80)(FMT(J),J=1,18)
   80 FORMAT(18A4)
   90 WRITE(IOU,92) TITLE,NCS,NXVB,NXVA,IPRINT,ITRAN,IREAD,NEWCH,
     1IUNIT,ISIN
   92 FORMAT(1H1,9HJOB TITLE,31X,12A4/10H NO. CASES,30X,I4/
     1 40H NO. DIMENSIONS BEFORE TRANSFORMATIONS   , I4/
     2 40H NO. DIMENSIONS AFTER TRANSFORMATIONS    , I4/           I
     3 40H PRINT OR MICROFILM OPTION               ,I4 /
     4 22H TRANSFORMATION OPTION,18X,I4/20H RE-READ DATA OPTION,20X,I4/
     5 23H ENTER NEW NAMES OPTION,17X,I4/
     6 40H OPTIONAL UNIT NUMBER FOR DATA SET       , I4 /
     7 40H OPTIONAL SIN FUNCTION                   , I4 )
      IF(IVAR(1,1).EQ.ITEST) GO TO 1400
      WRITE(IOU,390)
      WRITE(IOU,100)(I,(IVAR(I,J),J=1,5),I=1,NXVA)
  390 FORMAT(1H0///49H RESPECTIVE VARIABLE LISTING FOR CORRELATION WITH,
     126H TABLE OF LINEAR FUNCTIONS)
  100 FORMAT(4(6X,I3,3H - ,5A4))
 1400 DO 222 IJ = 1,NCS
      CALL READIN (NCS,X,NXVB,NXVA,ITRAN,IREAD,IPROB,FMT,IUNIT)
      CALL CALC(IJ,NXVA,X,F,FMAX,FMIN,ISIN)
  222 CONTINUE
      END FILE IALT
      REWIND IALT
      CALL ROWF($5000,NCS,NXVA,ANAM,F,FMAX,FMIN,TITLE,IPRINT,MIC,ITAB)
      STOP
      END
```

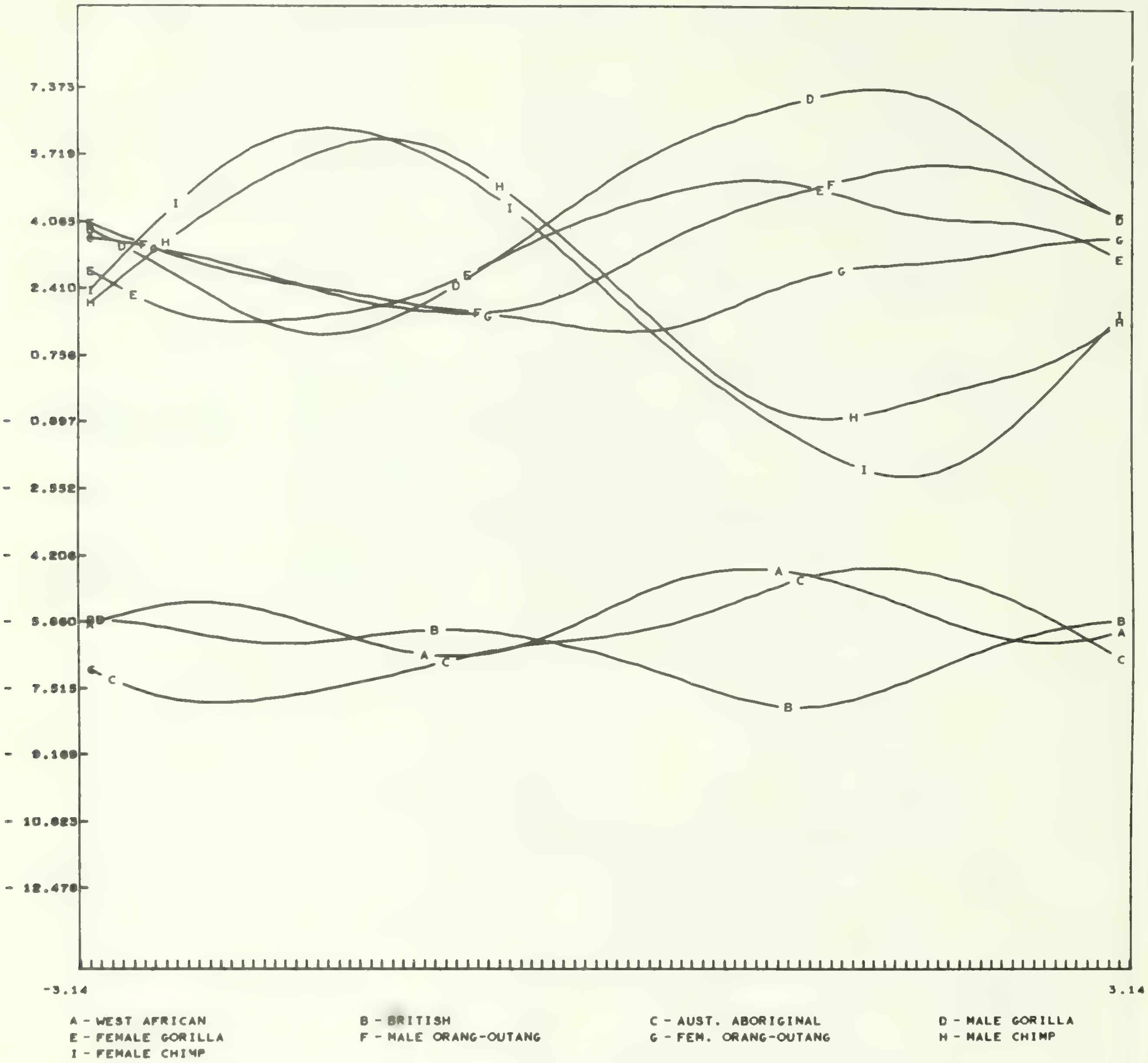
```
TITLE  ANDREWS ANTHROPOLOGICAL DATA                              15  8  8  1  0  0  1  0
W.  AFRICAN
BRITISH
AUST. ABOR.
GORILLA MALE
GORILLLA FEMALE
ORANG  MALE
ORANG  FEMALE
CHIMP  MALE
CHIMP  FEMALE
PITHECAN.
PEKIN.
PARA. ROBUS.
PARA.  CRAS.
MEGA.  PALA.
PROCON.  AFRIC.
( )
-8.09,.49,.18,.75,-.06,-.04,.04,.03
-9.37,-.68,-.44,-.37,.37,.02,-.01,.05
-8.87,1.44,.36,-.34,-.29,-.02,-.01,-.05
6.28,2.89,.43,-.03,.10,-.14,.07,.08
4.82,1.52,.71,-.06,.25,.15,-.07,-.10
5.11,1.61,-.72,.04,-.17,.13,.03,.05
3.6,.28,-1.05,.01,-.03,-.11,-.11,-.08
3.46,-3.37,.33,-.32,-.19,-.04,.09,.09
3.05,-4.21,.17,.28,.04,.02,-.06,-.06
-6.73,3.63,1.14,2.11,-1.9,.24,1.23,-.55
-5.9,3.95,.89,1.58,-1.56,1.10,1.53,0.58
-7.56,6.34,1.66,.1,-2.23,-1.01,.68,-.23,
-7.79,4.33,1.42,.01,-1.8,-.25,.04,-.87,
-8.23,5.03,1.13,-.02,-1.41,-.13,-.28,-.13
1.86,-4.28,-2.14,-1.73,2.06,1.8,2.61,2.48
PLOT    1, 15
PLOT    1,  9
LABEL ANDREWS MEANS OF GROUPS FOR APES AND MEN (LIVING)
PLOT   10, 15
LABEL  ANDREWS  FOSSILS
END
```

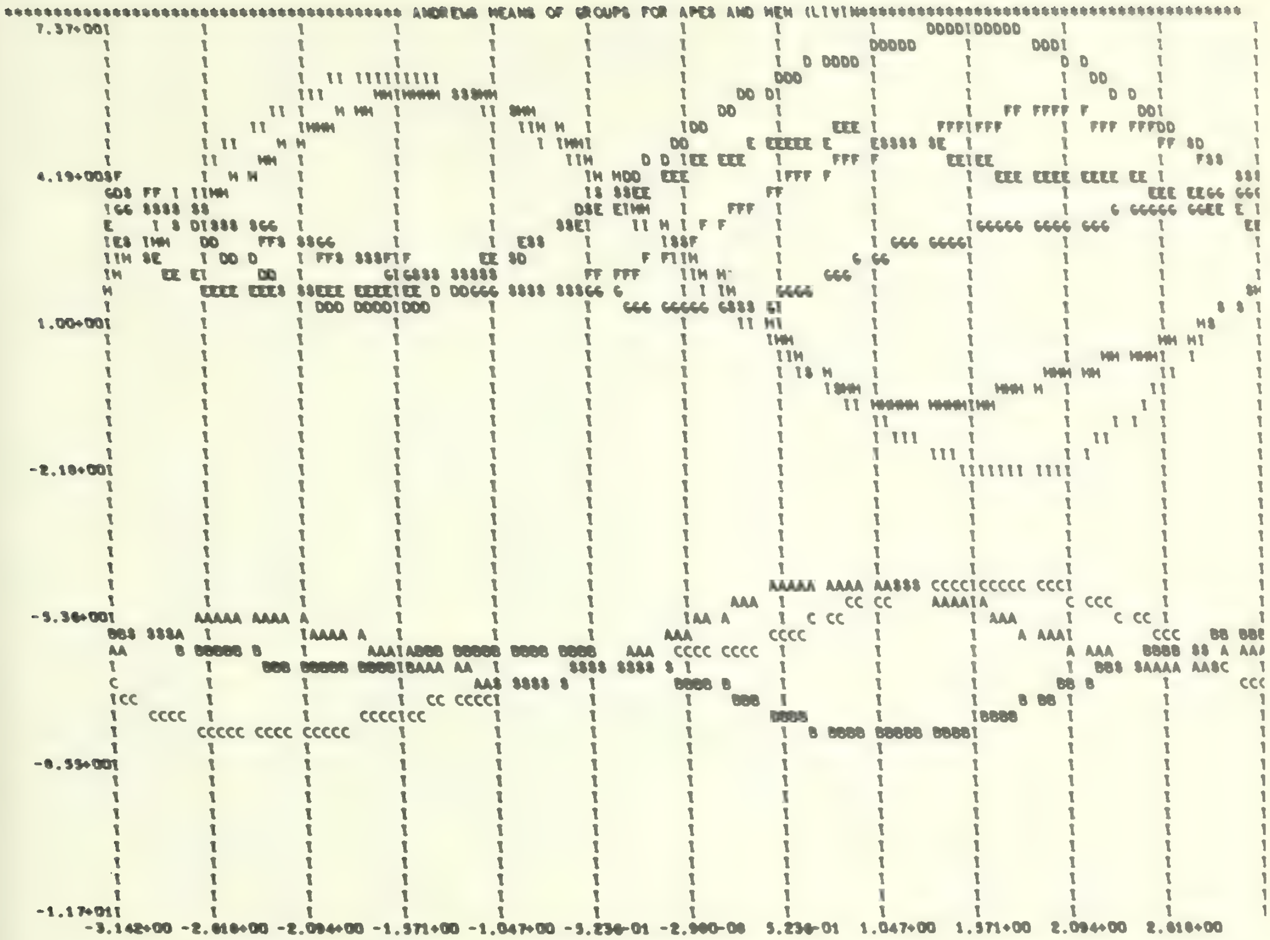
```
JOB TITLE                                    ANDREWS ANTHROPOLOGICAL DATA
NO. CASES                                   15
NO. DIMENSIONS BEFORE TRANSFORMATIONS        8
NO. DIMENSIONS AFTER TRANSFORMATIONS         8
PRINT OR MICROFILM OPTION                    1
TRANSFORMATION OPTION                        0
RE-READ DATA OPTION                          0
ENTER NEW NAMES OPTION                       1
OPTIONAL UNIT NUMBER FOR DATA SET            0
OPTIONAL SIN FUNCTION                        0
```



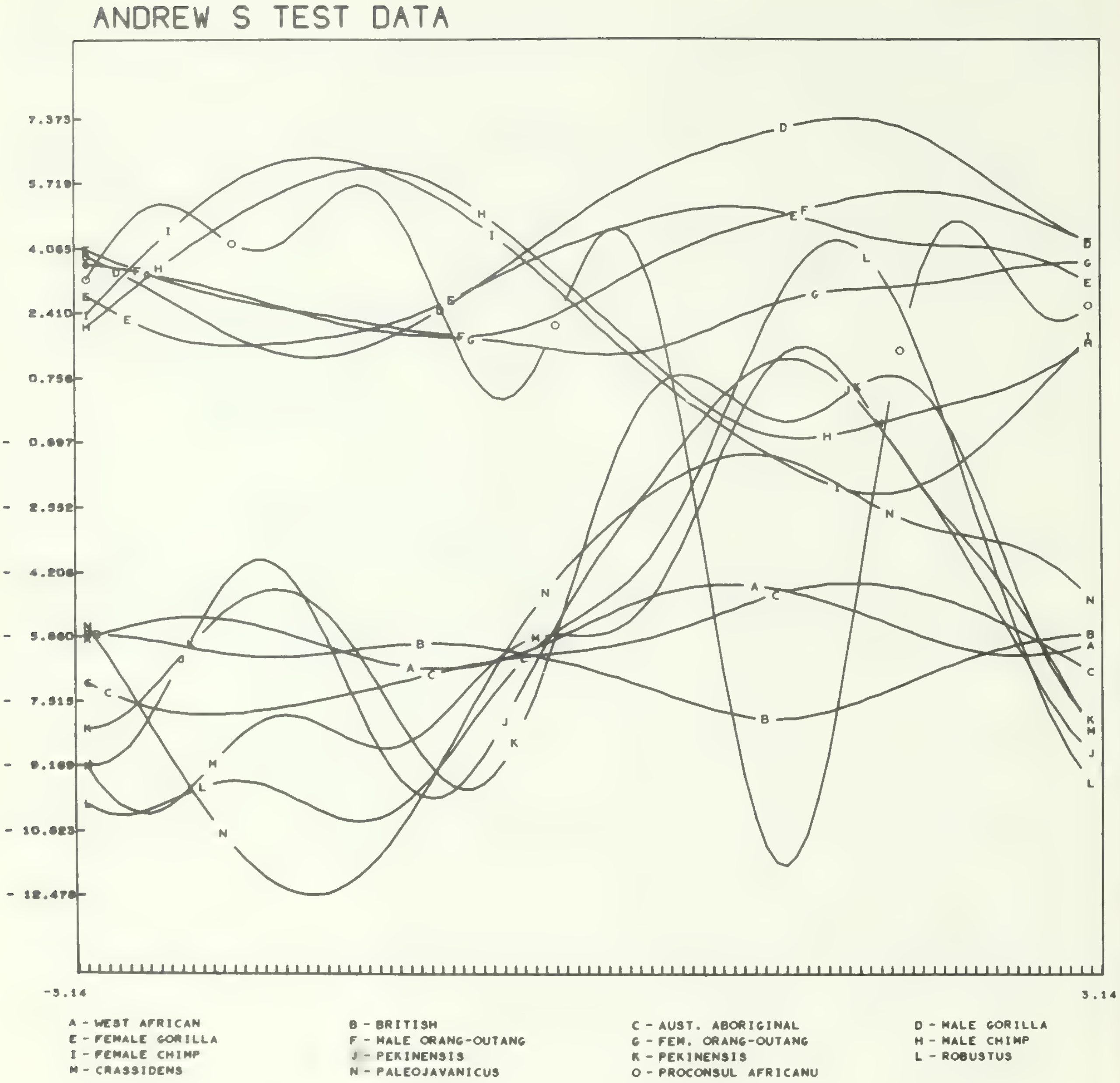
```
LABELS HAVE BEEN MODIFIED FOR READABILITY
     A  - W.  AFRICAN           B  - BRITISH              C  - AUST. ABOR.          D  - GORILLA MALE
     E  - GORILLLA FEMALE       F  - ORANG  MALE          G  - ORANG  FEMALE        H  - CHIMP  MALE
     I  - CHIMP  FEMALE         J  - PITHECAN.            K  - PEKIN.               L  - PARA. ROBUS.
     M  - PARA.  CRAS.          N  - MEGA.  PALA.         O  - PROCON.  AFRIC.
```

PLOT OF THE APES

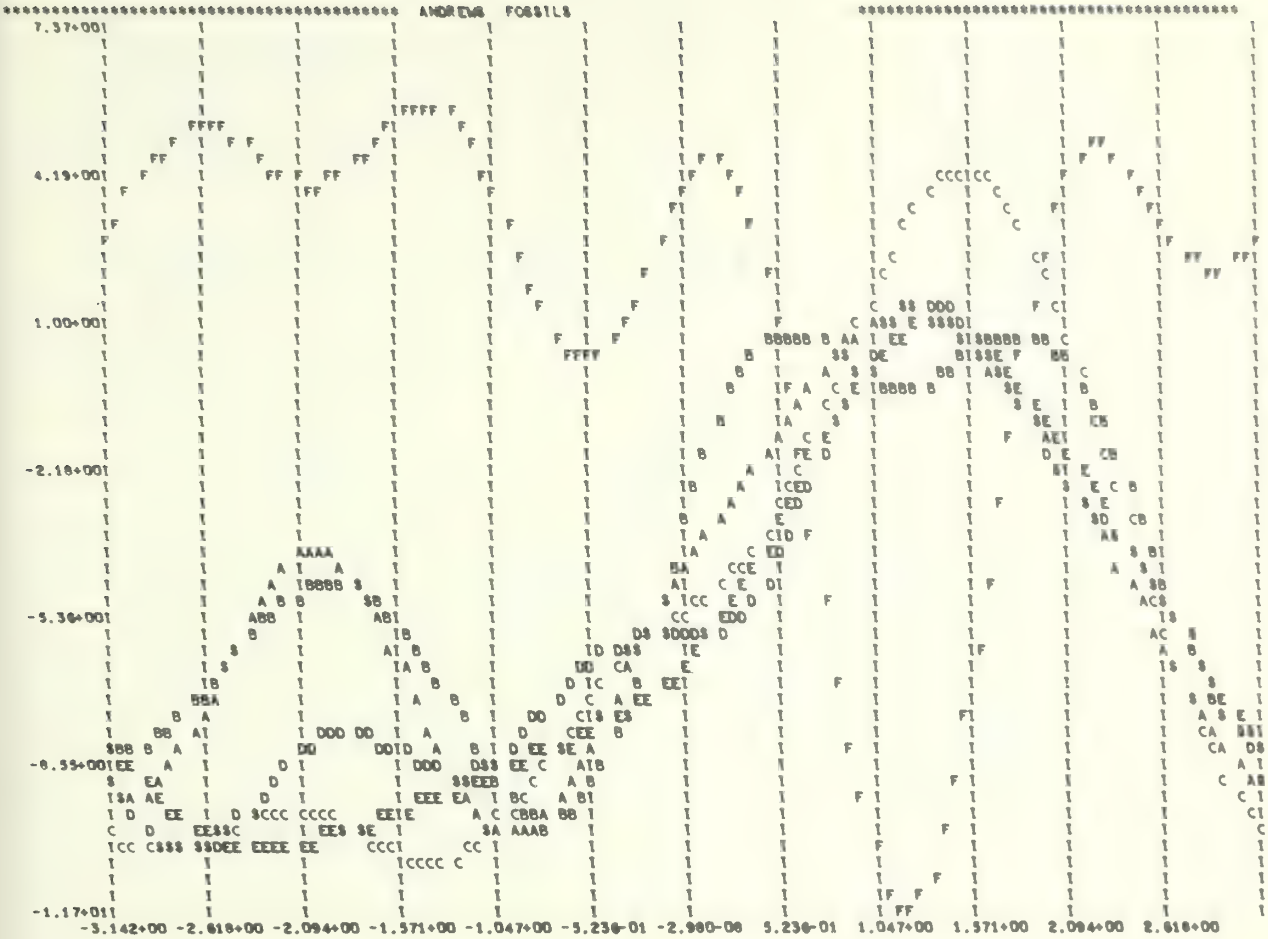




```
LABELS HAVE BEEN MODIFIED FOR READABILITY
      A  - W.  AFRICAN              B  - BRITISH                   C  - AUST. ABOR.              D  - GORILLA MALE
      E  - GORILLLA FEMALE          F  - ORANG  MALE               G  - ORANG  FEMALE            H  - CHIMP  MALE
      I  - CHIMP  FEMALE
```



ANDREW S TEST DATA



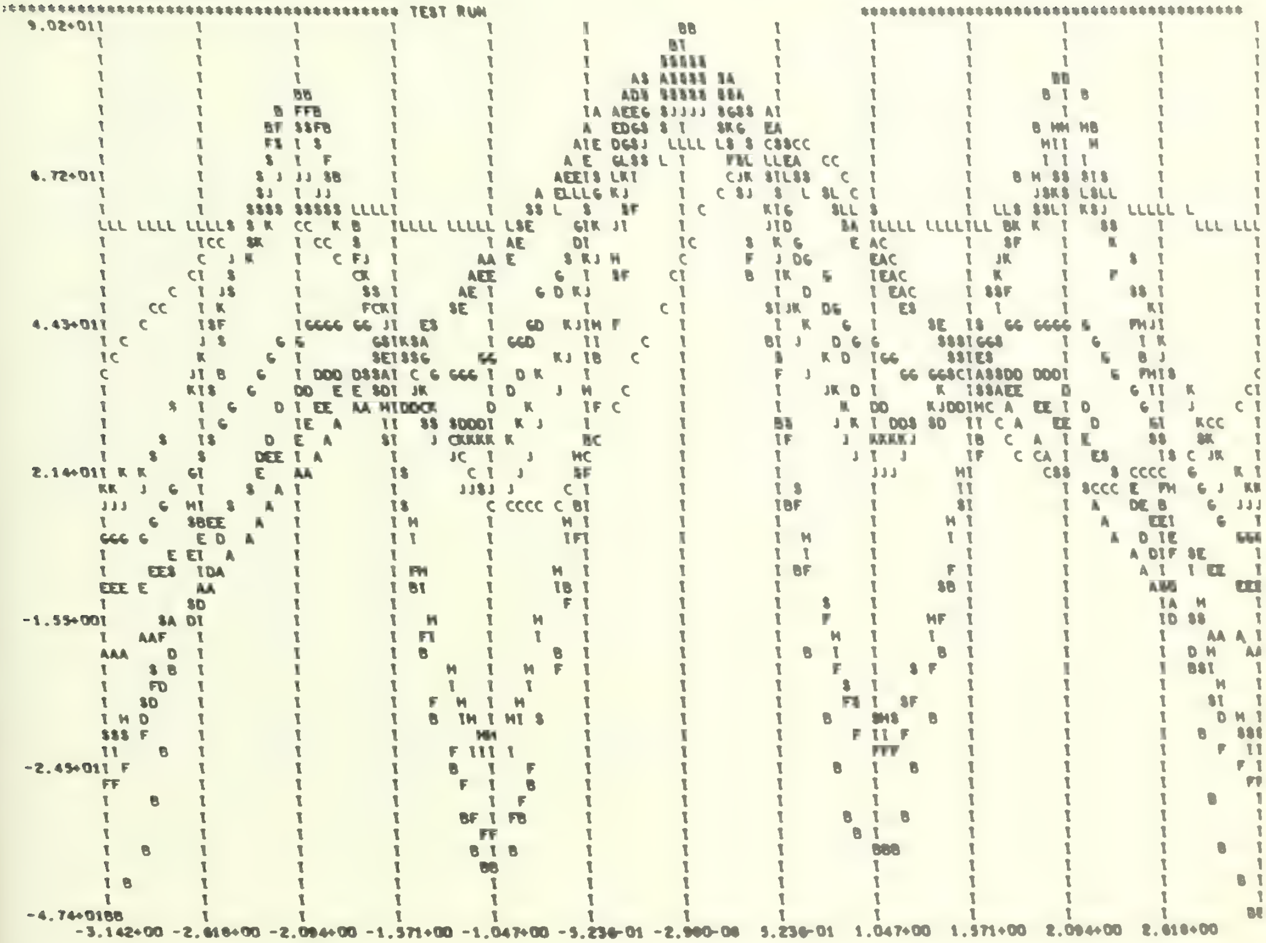
LABELS HAVE BEEN MODIFIED FOR READABILITY

A - PITHECAN. B - PEKIN. C - PARA. ROBUS. D - PARA. CRAS.
E - MEGA. PALA. F - PROCON. AFRIC.

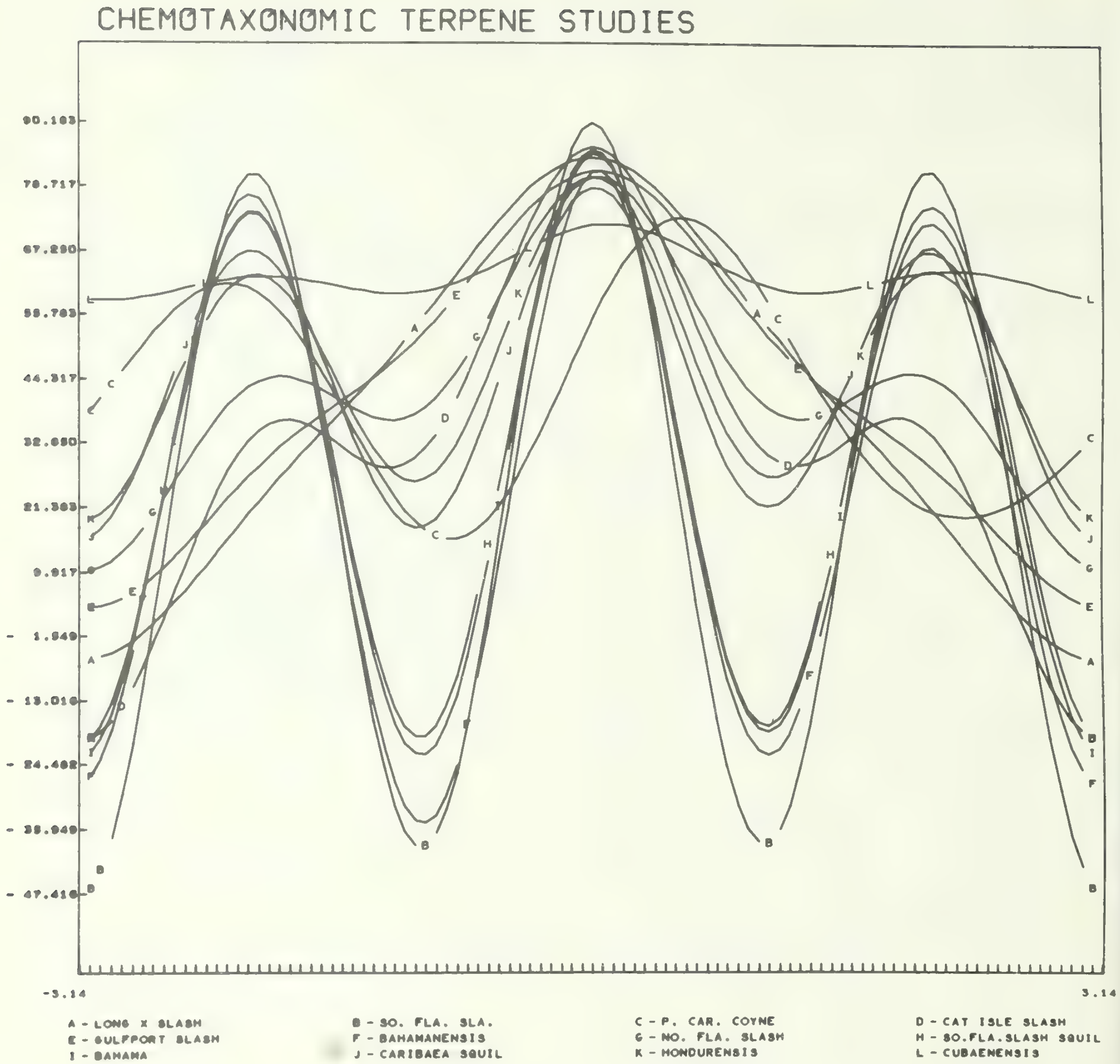
```
TITLE CHEMOTAXONOMIC TERPENE STUDIES                              12  7  7  1  0  0  2  0  0
LONG X SLASH
SO. FLA. SLA.
P. CAR. COYNE
CAT ISLE SLASH
GULFPORT SLASH
BAHAMANENSIS
NO. FLA. SLASH
SO.FLA.SLASH SQUIL
BAHAMA
CARIBAEA SQUIL
HONDURENSIS
CUBAENENSIS
ALPHA-PINENE
CAMPHENE
BETA-PINENE
DELTA-3-CARENENE
MYRCENE
LIMONENE
BETA-PHELANDRENE
( )
54.3,0.2,41.3,.0,.6,.0,3.6
30.1,0.4,5.8,.0,.1,.6,63.0
58.9,.8,5.6,23.7,3.8,3.8,3.6
46.5,.4,34.4,.0,.0,.3,18.5
58.2,.7,34.2,.0,1.4,.8,4.7
33.3,1.0,2.7,6.3,3.1,1.5,52.0
60.7,0.8,21.9,.0,2.4,1.1,13.2
41.7,1.0,4.2,0.3,2.9,1.3,48.7
39.4,.7,4.6,1.9,2.9,1.3,49.3
63.2,1.1,5.2,1.2,2.4,0.4,26.3
65.9,.6,8.2,0.1,3.1,1.1,22.4
89.0,.7,3.6,0.1,2.3,1.0,3.0
PLOT     1, 12
LABEL TEST RUN
```

```
JOB TITLE                                  CHEMOTAXONOMIC TERPENE STUDIES
NO. CASES                                  12
NO. DIMENSIONS BEFORE TRANSFORMATIONS       7
NO. DIMENSIONS AFTER TRANSFORMATIONS        7
PRINT OR MICROFILM OPTION                   1
TRANSFORMATION OPTION                       0
RE-READ DATA OPTION                         0
ENTER NEW NAMES OPTION                      2
OPTIONAL UNIT NUMBER FOR DATA SET           0
OPTIONAL SIN FUNCTION                       0


RESPECTIVE VARIABLE LISTING FOR CORRELATION WITH TABLE OF LINEAR FUNCTIONS
      1 - ALPHA-PINENE              2 - CAMPHENE               3 - BETA-PINENE                4 - DELTA-3-CARENENE
      5 - MYRCENE                   6 - LIMONENE               7 - BETA-PHELANDRENE
```



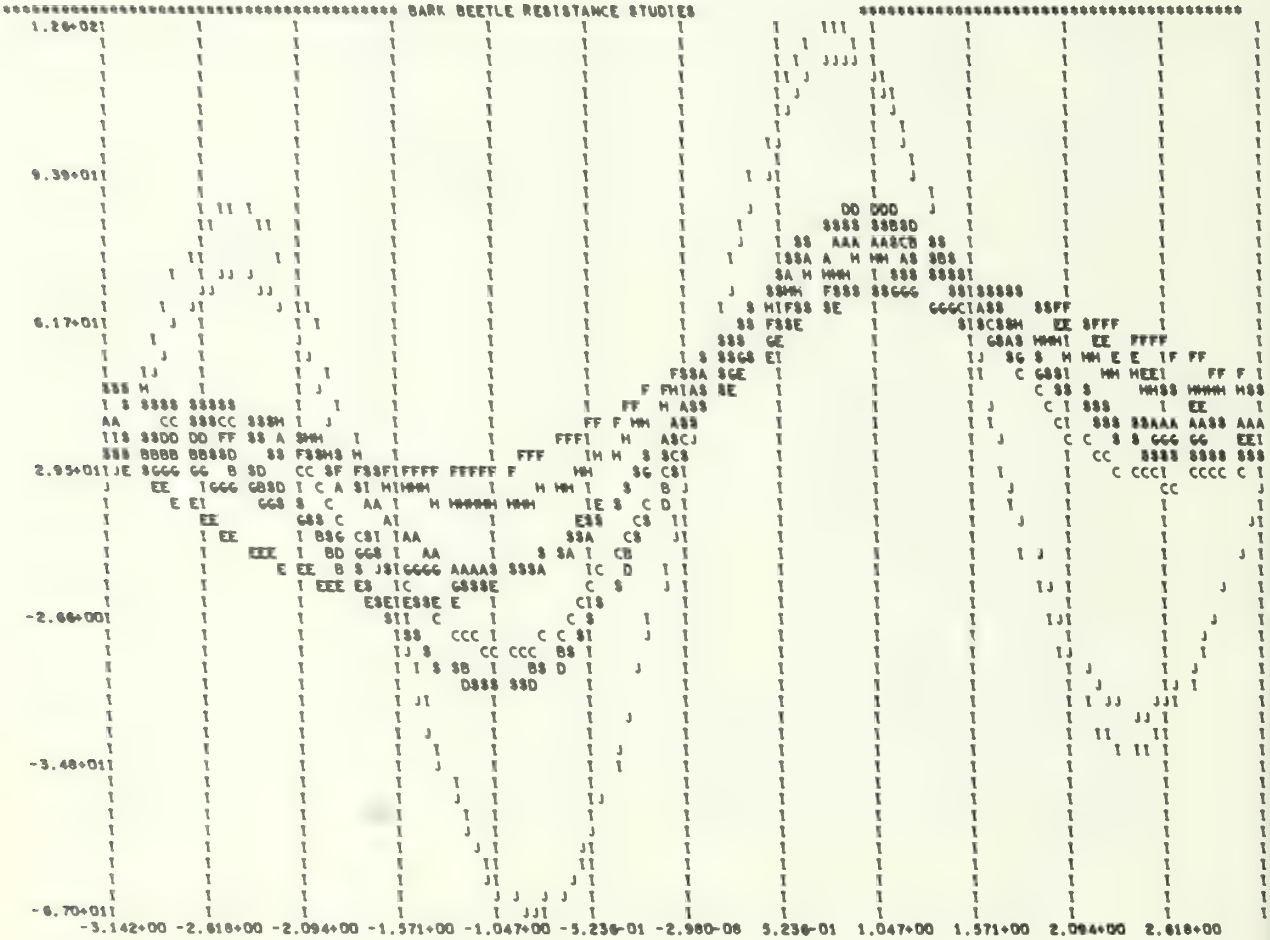
```
LABELS HAVE BEEN MODIFIED FOR READABILITY
     A  - LONG X SLASH            B  - SO. FLA. SLA.          C  - P. CAR. COYNE          D  - CAT ISLE SLASH
     E  - GULFPORT SLASH          F  - BAHAMANENSIS           G  - NO. FLA. SLASH         H  - SO.FLA.SLASH SQUIL
     I  - BAHAMA                  J  - CARIBAEA SQUIL         K  - HONDURENSIS            L  - CUBAENENSIS
```


CHEMOTAXONOMIC TERPENE STUDIES
90.183
78.717
67.250
55.783
44.317
32.850
21.383
9.917
- 1.549
- 13.016
- 24.482
- 35.949
- 47.416
-3.14
3.14
A - LONG X SLASH
B - SO. FLA. SLA.
C - P. CAR. COYNE
D - CAT ISLE SLASH
E - GULFPORT SLASH
F - BAHAMANENSIS
G - NO. FLA. SLASH
H - SO.FLA.SLASH SQUIL
I - BAHAMA
J - CARIBAEA SQUIL
K - HONDURENSIS
L - CUBAENENSIS

```
01
TITLE BARK BEETLE RESISTANCE STUDIES                          20  6  5  1  1  0  2  0  0
B1L
B2L
B4L
B13L
B14L
B100L
B101BL
B102L
B103L
B104L
B105L
B106L
B107L
B108L
B108XL
B140L
B141L
B142L
B143L
B144L
ALPHA-PINENE
BETA-PINENE
MYRCENE
LIMONENE
BETA-PHELANDRENE
( )
52.3,1.7,38.5,1.7,3.4,1.7
70.3,2.9,21.7,4.9,.0,.0
37.2,3.7,49.4,4.2,9.3,1.0
56.1,.6,34.7,4.4,3.,1.
50.6,.5,33.7,2.5,12.,.6
46.6,.5,38.9,2.3,10.7,1.1
50.5,.7,33.8,4.8,7.2,3.
38.7,.5,42.6,7.5,11.6,1.7
42.3,.7,46.8,2.4,5.5,1.3
60.8,.7,19.9,4.8,10.4,2.
60.2,.5,28.6,2.6,5.1,3.
47.7,.5,42.6,1.5,6.5,1.7
50.5,.7,33.8,4.8,7.2,3.
48.5,.5,43.0,.3,6.9,.7
51.3,.4,39.9,5.8,.8,1.9
70.1,.6,23.8,3.,.7,1.7
50.8,.6,30.2,7.7,2.9,7.9
67.3,1.,23.5,3.5,2.9,1.9
40.5,0.5,31.2,2.7,23.1,1.9
36.5,0.5,36.8,2.9,20.8,2.5
PLOT    11, 20
TITLE BARKBEETLE RESISTANCE STUDIES WITH SIN                   20  6  5  1  1  1  0  0  1
PLOT    11, 20
TITLE BBRS RECRDERED VARIABLES                                 20  6  5  1  1  1  3  0  0
LIMONENE
ALPHA-PINENE
BETA-PINENE
MYRCENE
BETA-PHELANDRENE
PLOT    11, 20
TITLE  BBRS RECRDERED VARIABLES WITH SIN                       20  6  5  1  1  1  0  0  1
PLOT    11, 20
```

```
JOB TITLE                                     BARKBEETLE RESISTANCE STUDIES WITH SIN
NO. CASES                                     20
NO. DIMENSIONS BEFORE TRANSFORMATIONS          6
NO. DIMENSIONS AFTER TRANSFORMATIONS           5
PRINT OR MICROFILM OPTION                      1
TRANSFORMATION OPTION                          1
RE-READ DATA OPTION                            1
ENTER NEW NAMES OPTION                         0
OPTIONAL UNIT NUMBER FOR DATA SET              0
OPTIONAL SIN FUNCTION                          1

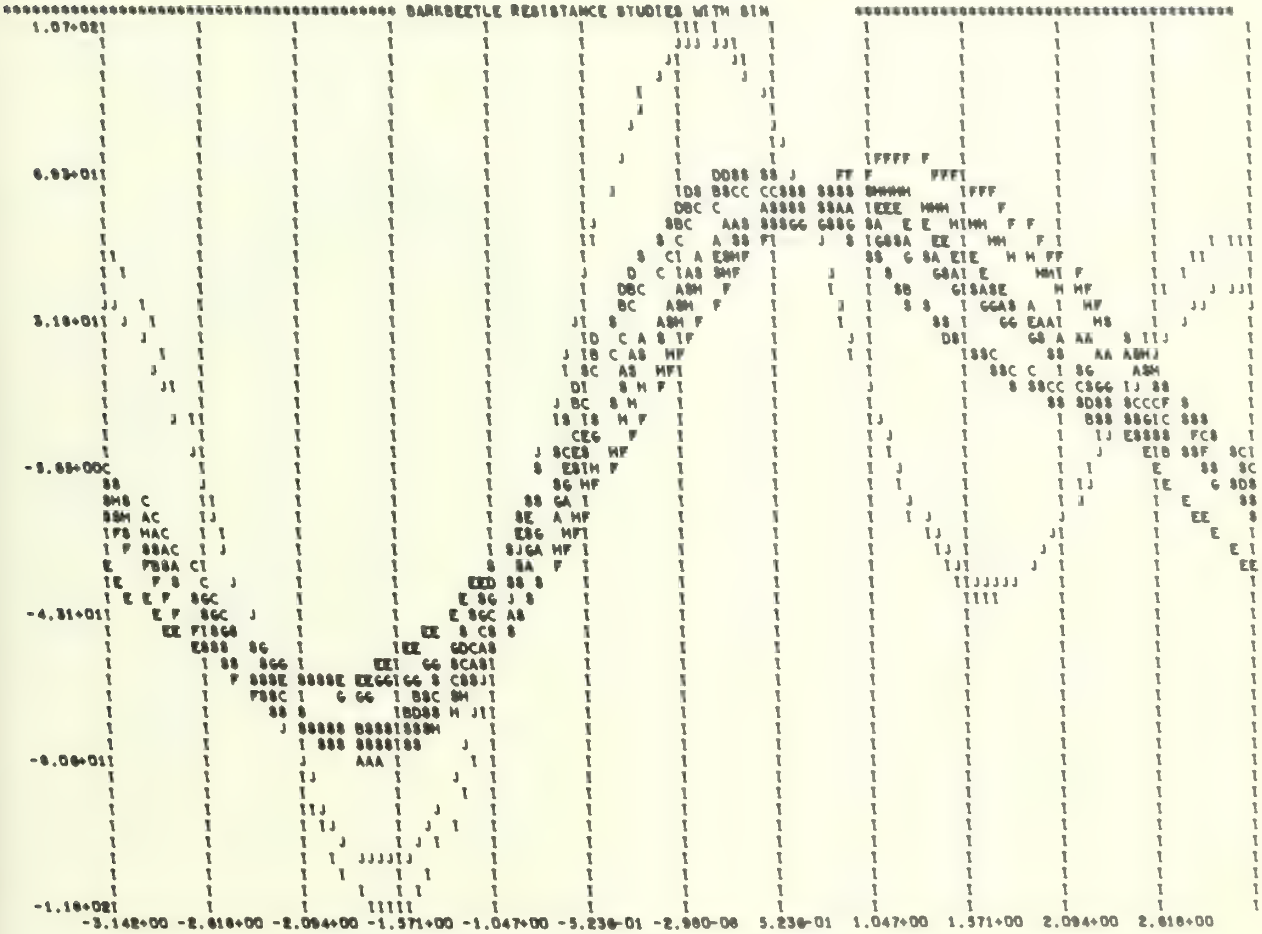

RESPECTIVE VARIABLE LISTING FOR CORRELATION WITH TABLE OF LINEAR FUNCTIONS
      1 - ALPHA-PINENE                  2 - BETA-PINENE                   3 - MYRCENE                          4 - LIMONENE
      5 - BETA-PHELANDRENE
```



```
LABELS HAVE BEEN MODIFIED FOR READABILITY
     A  - B103L                     B  - B106L                     C  - B107L                     D  - B108L
     E  - B108XL                    F  - B140L                     G  - B141L                     H  - B142L
     I  - B143L                     J  - B144L
```

```
JOB TITLE                                  BARK BEETLE RESISTANCE STUDIES
NO. CASES                                  20
NO. DIMENSIONS BEFORE TRANSFORMATIONS       6
NO. DIMENSIONS AFTER TRANSFORMATIONS        5
PRINT OR MICROFILM OPTION                   1
TRANSFORMATION OPTION                       1
RE-READ DATA OPTION                         0
ENTER NEW NAMES OPTION                      2
OPTIONAL UNIT NUMBER FOR DATA SET           0
OPTIONAL SIN FUNCTION                       0

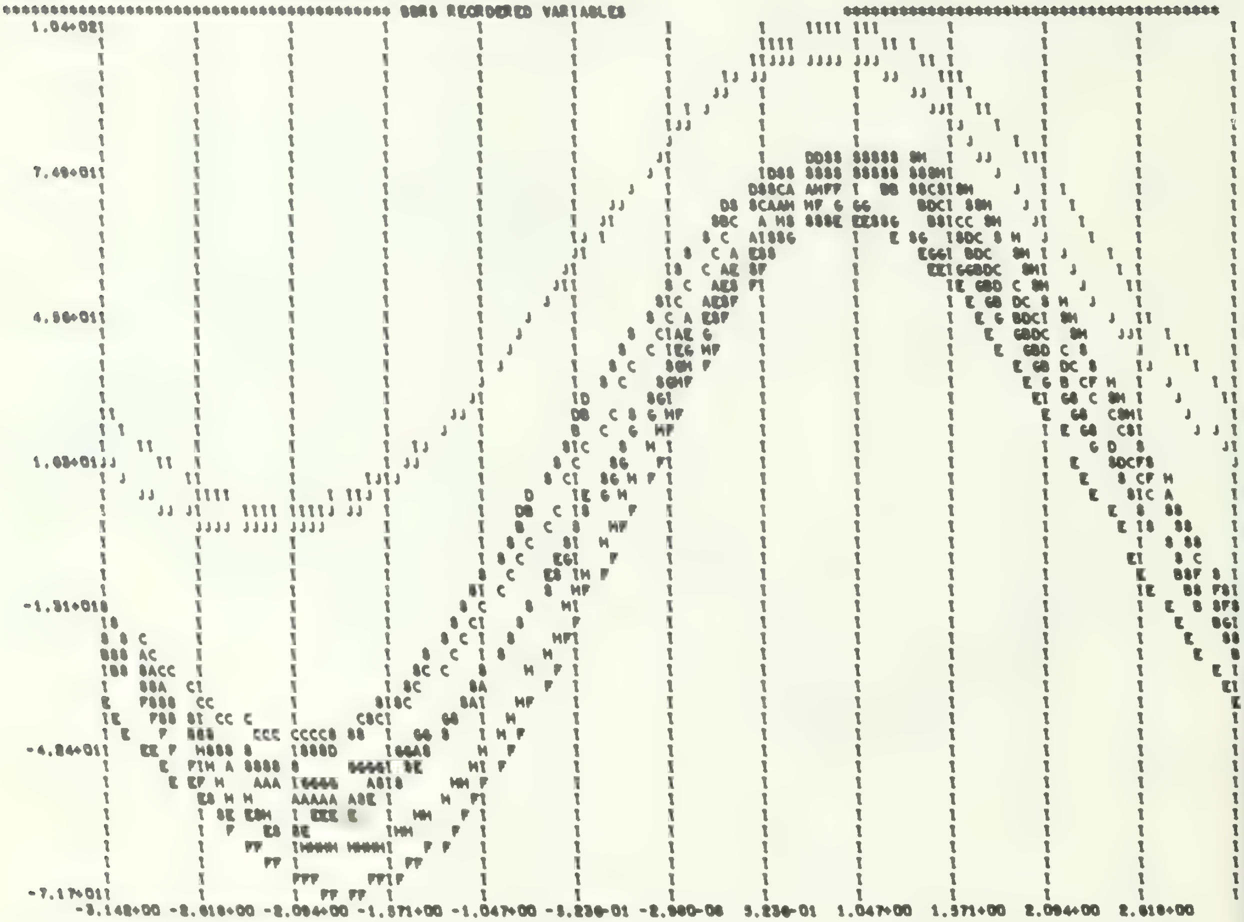

RESPECTIVE VARIABLE LISTING FOR CORRELATION WITH TABLE OF LINEAR FUNCTIONS
      1 - ALPHA-PINENE                   2 - BETA-PINENE                   3 - MYRCENE                             4 - LIMONENE
      5 - BETA-PHELANDRENE
```



```
LABELS HAVE BEEN MODIFIED FOR READABILITY
      A  - B105L                         B  - B106L                         C  - B107L                         D  - B108L
      E  - B108XL                        F  - B140L                         G  - B141L                         H  - B142L
      I  - B143L                         J  - B144L
```

```
JOB TITLE                                   BBRS REORDERED VARIABLES
NO. CASES                                   20
NO. DIMENSIONS BEFORE TRANSFORMATIONS        6
NO. DIMENSIONS AFTER TRANSFORMATIONS         5
PRINT OR MICROFILM OPTION                    1
TRANSFORMATION OPTION                        1
RE-READ DATA OPTION                          1
ENTER NEW NAMES OPTION                       3
OPTIONAL UNIT NUMBER FOR DATA SET            0
OPTIONAL SIN FUNCTION                        0


RESPECTIVE VARIABLE LISTING FOR CORRELATION WITH TABLE OF LINEAR FUNCTIONS
      1 - LIMONENE                    2 - ALPHA-PINENE                3 - BETA-PINENE                 4 - MYRCENE
      5 - BETA-PHELANDRENE
```

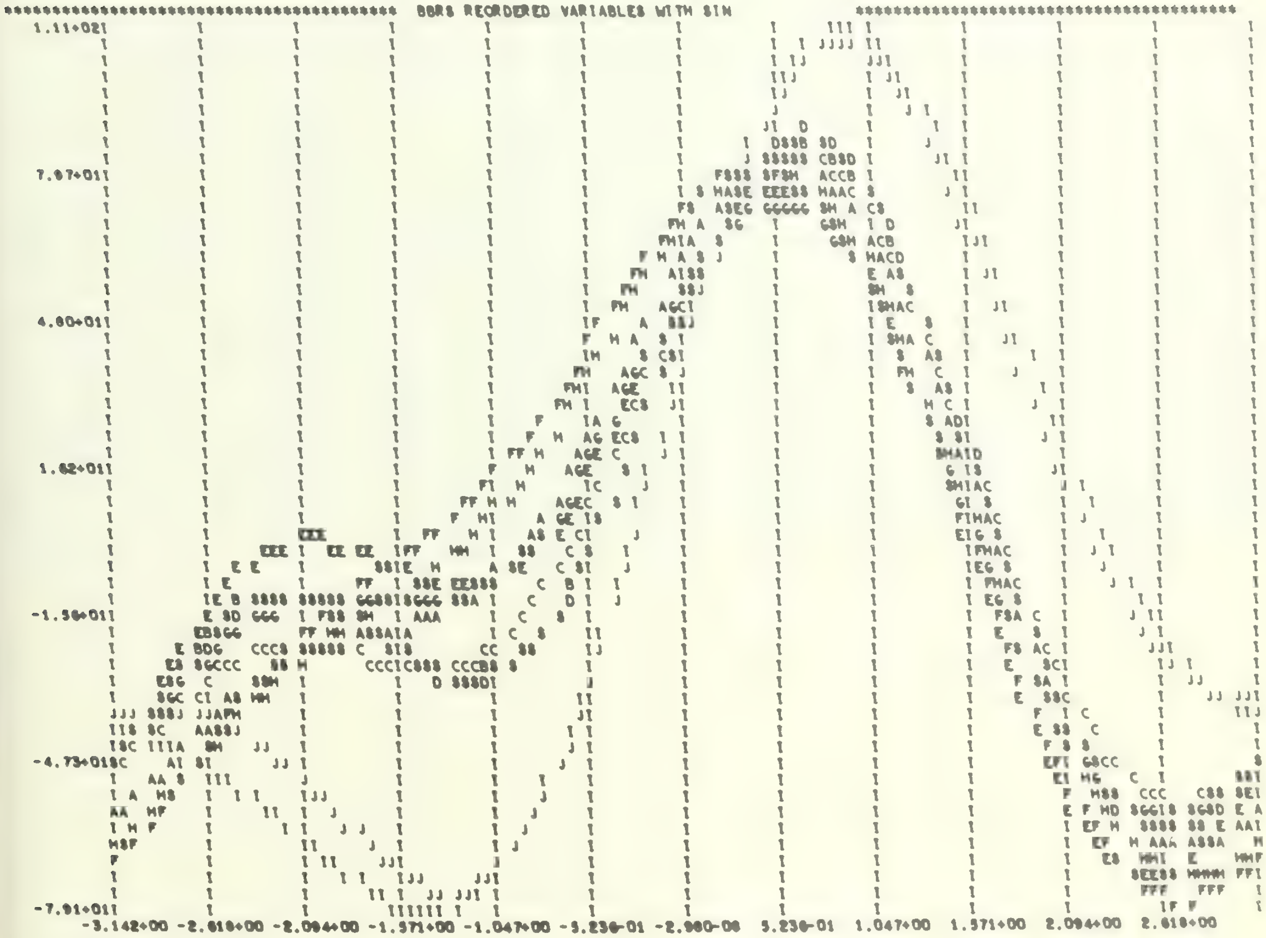


```
LABELS HAVE BEEN MODIFIED FOR READABILITY
      A  - B105L                      B  - B106L                      C  - B107L                      D  - B108L
      E  - B108XL                     F  - B140L                      G  - B141L                      H  - B142L
      I  - B143L                      J  - B144L
```

```
JOB TITLE                                 BBRS REORDERED VARIABLES WITH SIN
NO. CASES                                20
NO. DIMENSIONS BEFORE TRANSFORMATIONS     6
NO. DIMENSIONS AFTER TRANSFORMATIONS      5
PRINT OR MICROFILM OPTION                 1
TRANSFORMATION OPTION                     1
RE-READ DATA OPTION                       1
ENTER NEW NAMES OPTION                    0
OPTIONAL UNIT NUMBER FOR DATA SET         0
OPTIONAL SIN FUNCTION                     1



RESPECTIVE VARIABLE LISTING FOR CORRELATION WITH TABLE OF LINEAR FUNCTIONS
       1 - LIMONENE                      2 - ALPHA-PINENE                     3 - BETA-PINENE                       4 - MYRCENE
       5 - BETA-PHELANDRENE
```



```
LABELS HAVE BEEN MODIFIED FOR READABILITY
      A  - B105L                  B  - B106L                       C  - B107L                     D  - B108L
      E  - B108XL                 F  - B140L                       G  - B141L                     H  - B142L
      I  - B143L                  J  - B144L
```

TABLE OF LINEAR FUNCTIONS FOR ANDREWS PLOTTING METHOD

VALUES OF T

	-3.14	-3.08	-3.01	-2.95	-2.88	-2.82	-2.76	-2.69	-2.63	-2.56	-2.50	-2.44	-2.37	-2.31	-2.24	-2.18	-2.12	-2.05	-1.99	-1.92
1	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71
2	.00	-.06	-.13	-.19	-.25	-.32	-.38	-.43	-.49	-.55	-.60	-.65	-.70	-.74	-.78	-.82	-.85	-.89	-.91	-.94
3	-1.00	-1.00	-.99	-.98	-.97	-.95	-.93	-.90	-.87	-.84	-.80	-.76	-.72	-.67	-.62	-.57	-.52	-.46	-.41	-.34
4	.00	.13	.25	.38	.49	.60	.70	.78	.85	.91	.96	.99	1.00	.99	.98	.94	.89	.82	.74	.65
5	1.00	.99	.97	.93	.87	.80	.72	.62	.52	.41	.29	.16	.03	-.10	-.22	-.34	-.46	-.57	-.67	-.76
6	.00	-.19	-.38	-.55	-.70	-.82	-.91	-.98	-1.00	-.99	-.94	-.85	-.74	-.60	-.43	-.25	-.06	.13	.32	.49
7	-1.00	-.98	-.93	-.84	-.72	-.57	-.41	-.22	-.03	.16	.34	.52	.67	.80	.90	.97	1.00	.99	.95	.87
8	.00	.25	.49	.70	.85	.96	1.00	.98	.89	.74	.55	.32	.06	-.19	-.43	-.65	-.82	-.94	-.99	-.99
9	1.00	.97	.87	.72	.52	.29	.03	-.22	-.46	-.67	-.84	-.95	-1.00	-.98	-.90	-.76	-.57	-.34	-.10	.16
10	.00	-.32	-.60	-.82	-.96	-1.00	-.94	-.78	-.55	-.25	.06	.38	.65	.85	.98	.99	.91	.74	.49	.19
11	-1.00	-.95	-.80	-.57	-.29	.03	.34	.62	.84	.97	1.00	.93	.76	.52	.22	-.10	-.41	-.67	-.87	-.98
12	.00	.38	.70	.91	1.00	.94	.74	.43	.06	-.32	-.65	-.89	-.99	-.96	-.78	-.49	-.13	.25	.60	.85
13	1.00	.93	.72	.41	.03	-.34	-.67	-.90	-1.00	-.95	-.76	-.46	-.10	.29	.62	.87	.99	.97	.80	.52
14	.00	-.43	-.78	-.98	-.98	-.78	-.43	.00	.43	.78	.98	.98	.78	.43	.00	-.43	-.78	-.98	-.98	-.78
15	-1.00	-.90	-.62	-.22	.22	.62	.90	1.00	.90	.62	.22	-.22	-.62	-.90	-1.00	-.90	-.62	-.22	.22	.62
16	.00	.49	.85	1.00	.89	.55	.06	-.43	-.82	-.99	-.91	-.60	-.13	.38	.78	.99	.94	.65	.19	-.32
17	1.00	.87	.52	.03	-.46	-.84	-1.00	-.90	-.57	-.10	.41	.80	.99	.93	.62	.16	-.34	-.76	-.98	-.95
18	.00	-.55	-.91	-.99	-.74	-.25	.32	.78	.99	.89	.49	-.06	-.60	-.94	-.98	-.70	-.19	.38	.82	1.00
19	-1.00	-.84	-.41	.16	.67	.97	.95	.62	.10	-.46	-.87	-1.00	-.80	-.34	.22	.72	.98	.93	.57	.03
20	.00	.60	.96	.94	.55	-.06	-.65	-.98	-.91	-.49	.13	.70	.99	.89	.43	-.19	-.74	-.99	-.85	-.38
21	1.00	.80	.29	-.34	-.84	-1.00	-.76	-.22	.41	.87	.99	.72	.16	-.46	-.90	-.98	-.67	-.10	.52	.93
22	.00	-.65	-.99	-.85	-.32	.38	.89	.98	.60	-.06	-.70	-.99	-.82	-.25	.43	.91	.96	.55	-.13	-.74
23	-1.00	-.76	-.16	.52	.95	.93	.46	-.22	-.80	-1.00	-.72	-.10	.57	.97	.90	.41	-.29	-.84	-.99	-.67
24	.00	.70	1.00	.74	.06	-.65	-.99	-.78	-.13	.60	.99	.82	.19	-.55	-.98	-.85	-.25	.49	.96	.89
25	1.00	.72	.03	-.67	-1.00	-.76	-.10	.62	.99	.80	.16	-.57	-.98	-.84	-.22	.52	.97	.87	.29	-.46
26	.00	-.74	-.99	-.60	.19	.85	.96	.43	-.38	-.94	-.89	-.25	.55	.99	.78	.06	-.70	-1.00	-.65	.13
27	-1.00	-.67	.10	.80	.98	.52	-.29	-.90	-.93	-.34	.46	.97	.84	.16	-.62	-1.00	-.72	.03	.76	.99
28	.00	.78	.98	.43	-.43	-.98	-.78	.00	.78	.98	.43	-.43	-.98	-.78	.00	.78	.98	.43	-.43	-.98
29	1.00	.62	-.22	-.90	-.90	-.22	.62	1.00	.62	-.22	-.90	-.90	-.22	.62	1.00	.62	-.22	-.90	-.90	-.22
30	.00	-.82	-.94	-.25	.65	.99	.49	-.43	-.99	-.70	.19	.91	.85	.06	-.78	-.96	-.32	.60	1.00	.55
31	-1.00	-.57	.34	.97	.76	-.10	-.87	-.90	-.16	.72	.98	.41	-.52	-1.00	-.62	.29	.95	.80	-.03	-.84
32	.00	.85	.89	.06	-.82	-.91	-.13	.78	.94	.19	-.74	-.96	-.25	.70	.98	.32	-.65	-.99	-.38	.60
33	1.00	.52	-.46	-1.00	-.57	.41	.99	.62	-.34	-.98	-.67	.29	.97	.72	-.22	-.95	-.76	.16	.93	.80
34	.00	-.89	-.82	.13	.94	.74	-.25	-.98	-.65	.38	.99	.55	-.49	-1.00	-.43	.60	.99	.32	-.70	-.96
35	-1.00	-.46	.57	.99	.34	-.67	-.97	-.22	.76	.93	.10	-.84	-.87	.03	.90	.80	-.16	-.95	-.72	.29
36	.00	.91	.74	-.32	-.99	-.49	.60	.98	.19	-.82	-.85	.13	.96	.65	-.43	-1.00	-.38	.70	.94	.06
37	1.00	.41	-.67	-.95	-.10	.87	.80	-.22	-.98	-.57	.52	.99	.29	-.76	-.90	.03	.93	.72	-.34	-1.00
38	.00	-.94	-.65	.49	.99	.19	-.85	-.78	.32	1.00	.38	-.74	-.89	.13	.98	.55	-.60	-.96	-.06	.91
39	-1.00	-.34	.76	.87	-.16	-.98	-.52	.62	.95	.03	-.93	-.67	.46	.99	.22	-.84	-.80	.29	1.00	.41
40	.00	.96	.55	-.65	-.91	.13	.99	.43	-.74	-.85	.25	1.00	.32	-.82	-.78	.38	.99	.19	-.89	-.70
41	1.00	.29	-.84	-.76	.41	.99	.16	-.90	-.67	.52	.97	.03	-.95	-.57	.62	.93	-.10	-.98	-.46	.72
42	.00	-.98	-.43	.78	.78	-.43	-.98	.00	.98	.43	-.78	-.78	.43	.98	.00	-.98	-.43	.78	.78	-.43
43	-1.00	-.22	.90	.62	-.62	-.90	.22	1.00	.22	-.90	-.62	.62	.90	-.22	-1.00	-.22	.90	.62	-.62	-.90
44	.00	.99	.32	-.89	-.60	.70	.82	-.43	-.96	.13	1.00	.19	-.94	-.49	.78	.74	-.55	-.91	.25	.99
45	1.00	.16	-.95	-.46	.80	.72	-.57	-.90	.29	.99	.03	-.98	-.34	.87	.62	-.67	-.84	.41	.97	-.10
46	.00	-.99	-.19	.96	.38	-.89	-.55	.78	.70	-.65	-.82	.49	.91	-.32	-.98	.13	1.00	.06	-.99	-.25
47	-1.00	-.10	.98	.29	-.93	-.46	.84	.62	-.72	-.76	.57	.87	-.41	-.95	.22	.99	-.03	-1.00	-.16	.97
48	.00	1.00	.06	-.99	-.13	.99	.19	-.98	-.25	.96	.32	-.94	-.38	.91	.43	-.89	-.49	.85	.55	-.82
49	1.00	.03	-1.00	-.10	.99	.16	-.98	-.22	.97	.29	-.95	-.34	.93	.41	-.90	-.46	.87	.52	-.84	-.57
50	.00	-1.00	.06	.99	-.13	-.99	.19	.98	-.25	-.96	.32	.94	-.38	-.91	.43	.89	-.49	-.85	.55	.82

TABLE OF LINEAR FUNCTIONS FOR ANDREWS PLOTTING METHOD

VALUES OF T

	-1.86	-1.80	-1.73	-1.67	-1.60	-1.54	-1.47	-1.41	-1.35	-1.28	-1.22	-1.15	-1.09	-1.03	-.96	-.90	-.83	-.77	-.70	-.64
1	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71
2	-.96	-.98	-.99	-.99	-1.00	-1.00	-.99	-.99	-.98	-.96	-.94	-.91	-.89	-.85	-.82	-.78	-.74	-.70	-.65	-.60
3	-.29	-.22	-.16	-.10	-.03	.03	.10	.16	.22	.29	.34	.41	.46	.52	.57	.62	.67	.72	.76	.80
4	.55	.43	.32	.19	.06	-.06	-.19	-.32	-.43	-.55	-.65	-.74	-.82	-.89	-.94	-.98	-.99	-1.00	-.99	-.96
5	-.84	-.90	-.95	-.98	-1.00	-1.00	-.98	-.95	-.90	-.84	-.76	-.67	-.57	-.46	-.34	-.22	-.10	.03	.16	.29
6	.65	.78	.89	.96	.99	.99	.96	.89	.78	.65	.49	.32	.13	-.06	-.25	-.43	-.60	-.74	-.85	-.94
7	.76	.62	.46	.29	.10	-.10	-.29	-.46	-.62	-.76	-.87	-.95	-.99	-1.00	-.97	-.90	-.80	-.67	-.52	-.34
8	-.91	-.78	-.60	-.38	-.13	.13	.38	.60	.78	.91	.99	.99	.94	.82	.65	.43	.19	-.06	-.32	-.55
9	.41	.62	.80	.93	.99	.99	.93	.80	.62	.41	.16	-.10	-.34	-.57	-.76	-.90	-.98	-1.00	-.95	-.84
10	-.13	-.43	-.70	-.89	-.99	-.99	-.89	-.70	-.43	-.13	.19	.49	.74	.91	.99	.98	.85	.65	.38	.06
11	-.99	-.90	-.72	-.46	-.16	.16	.46	.72	.90	.99	.98	.87	.67	.41	.10	-.22	-.52	-.76	-.93	-1.00
12	.99	.98	.82	.55	.19	-.19	-.55	-.82	-.98	-.99	-.85	-.60	-.25	.13	.49	.78	.96	.99	.89	.65
13	.16	-.22	-.57	-.84	-.98	-.98	-.84	-.57	-.22	.16	.52	.80	.97	.99	.87	.62	.29	-.10	-.46	-.76
14	-.43	.00	.43	.78	.98	.98	.78	.43	.00	-.43	-.78	-.98	-.98	-.78	-.43	.00	.43	.78	.98	.98
15	.90	1.00	.90	.62	.22	-.22	-.62	-.90	-1.00	-.90	-.62	-.22	.22	.62	.90	1.00	.90	.62	.22	-.22
16	-.74	-.98	-.96	-.70	-.25	.25	.70	.96	.98	.74	.32	-.19	-.65	-.94	-.99	-.78	-.38	.13	.60	.91
17	-.67	-.22	.29	.72	.97	.97	.72	.29	-.22	-.67	-.95	-.98	-.76	-.34	.16	.62	.93	.99	.80	.41
18	.85	.43	-.13	-.65	-.96	-.96	-.65	-.13	.43	.85	1.00	.82	.38	-.19	-.70	-.98	-.94	-.60	-.06	.49
19	-.52	-.90	-.99	-.76	-.29	.29	.76	.99	.90	.52	-.03	-.57	-.93	-.98	-.72	-.22	.34	.80	1.00	.87
20	.25	.78	1.00	.82	.32	-.32	-.82	-1.00	-.78	-.25	.38	.85	.99	.74	.19	-.43	-.89	-.99	-.70	-.13
21	.97	.62	.03	-.57	-.95	-.95	-.57	.03	.62	.97	.93	.52	-.10	-.67	-.98	-.90	-.46	.16	.72	.99
22	-1.00	-.78	-.19	.49	.94	.94	.49	-.19	-.78	-1.00	-.74	-.13	.55	.96	.91	.43	-.25	-.82	-.99	-.70
23	-.03	.62	.98	.87	.34	-.34	-.87	-.98	-.62	.03	.67	.99	.84	.29	-.41	-.90	-.97	-.57	.10	.72
24	.32	-.43	-.94	-.91	-.38	.38	.91	.94	.43	-.32	-.89	-.96	-.49	.25	.85	.98	.55	-.19	-.82	-.99
25	-.95	-.90	-.34	.41	.93	.93	.41	-.34	-.90	-.95	-.46	.29	.87	.97	.52	-.22	-.84	-.98	-.57	.16
26	.82	.98	.49	-.32	-.91	-.91	-.32	.49	.98	.82	.13	-.65	-1.00	-.70	.06	.78	.99	.55	-.25	-.89
27	.57	-.22	-.87	-.95	-.41	.41	.95	.87	.22	-.57	-.99	-.76	-.03	.72	1.00	.62	-.16	-.84	-.97	-.46
28	-.78	.00	.78	.98	.43	-.43	-.98	-.78	.00	.78	.98	.43	-.43	-.98	-.78	.00	.78	.98	.43	-.43
29	.62	1.00	.62	-.22	-.90	-.90	-.22	.62	1.00	.62	-.22	-.90	-.90	-.22	.62	1.00	.62	-.22	-.90	-.90
30	-.38	-.98	-.74	.13	.89	.89	.13	-.74	-.98	-.38	.55	1.00	.60	-.32	-.96	-.78	.06	.85	.91	.19
31	-.93	-.22	.67	.99	.46	-.46	-.99	-.67	.22	.93	.84	.03	-.80	-.95	-.29	.62	1.00	.52	-.41	-.98
32	.99	.43	-.55	-1.00	-.49	.49	1.00	.55	-.43	-.99	-.60	.38	.99	.65	-.32	-.98	-.70	.25	.96	.74
33	-.10	-.90	-.84	.03	.87	.87	.03	-.84	-.90	-.10	.80	.93	.16	-.76	-.95	-.22	.72	.97	.29	-.67
34	-.19	.78	.91	.06	-.85	-.85	.06	.91	.78	-.19	-.96	-.70	.32	.99	.60	-.43	-1.00	-.49	.55	.99
35	.98	.62	-.41	-1.00	-.52	.52	1.00	.41	-.62	-.98	-.29	.72	.95	.16	-.80	-.90	-.03	.87	.84	-.10
36	-.89	-.78	.25	.99	.55	-.55	-.99	-.25	.78	.89	-.06	-.94	-.70	.38	1.00	.43	-.65	-.96	-.13	.85
37	-.46	.62	.97	.16	-.84	-.84	.16	.97	.62	-.46	-1.00	-.34	.72	.93	.03	-.90	-.76	.29	.99	.52
38	.70	-.43	-.99	-.25	.82	.82	-.25	-.99	-.43	.70	.91	-.06	-.96	-.60	.55	.98	.13	-.89	-.74	.38
39	-.72	-.90	.10	.97	.57	-.57	-.97	-.10	.90	.72	-.41	-1.00	-.29	.80	.84	-.22	-.99	-.46	.67	.93
40	.49	.98	.06	-.94	-.60	.60	.94	-.06	-.98	-.49	.70	.89	-.19	-.99	-.38	.78	.82	-.32	-1.00	-.25
41	.87	-.22	-1.00	-.34	.80	.80	-.34	-1.00	-.22	.87	.72	-.46	-.98	-.10	.93	.62	-.57	-.95	.03	.97
42	-.98	.00	.98	.43	-.78	-.78	.43	.98	.00	-.98	-.43	.78	.78	-.43	-.98	.00	.98	.43	-.78	-.78
43	.22	1.00	.22	-.90	-.62	.62	.90	-.22	-1.00	-.22	.90	.62	-.62	-.90	.22	1.00	.22	-.90	-.62	.62
44	.06	-.98	-.38	.85	.65	-.65	-.85	.38	.98	-.06	-.99	-.25	.91	.55	-.74	-.78	.49	.94	-.19	-1.00
45	-1.00	-.22	.93	.52	-.76	-.76	.52	.93	-.22	-1.00	-.10	.97	.41	-.84	-.67	.62	.87	-.34	-.98	.03
46	.94	.43	-.85	-.60	.74	.74	-.60	-.85	.43	.94	-.25	-.99	.06	1.00	.13	-.98	-.32	.91	.49	-.82
47	.34	-.90	-.52	.80	.67	-.67	-.80	.52	.90	-.34	-.97	.16	1.00	.03	-.99	-.22	.95	.41	-.87	-.57
48	-.60	.78	.65	-.74	-.70	.70	.74	-.65	-.78	.60	.82	-.55	-.85	.49	.89	-.43	-.91	.38	.94	-.32
49	.80	.62	-.76	-.67	.72	.72	-.67	-.76	.62	.80	-.57	-.84	.52	.87	-.46	-.90	.41	.93	-.34	-.95
50	-.60	-.78	.65	.74	-.70	-.70	.74	.65	-.78	-.60	.82	.55	-.85	-.49	.89	.43	-.91	-.38	.94	.32

TABLE OF LINEAR FUNCTIONS FOR ANDREWS PLOTTING METHOD

VALUES OF T

	-.58	-.51	-.45	-.39	-.32	-.26	-.19	-.13	-.06	.00	.06	.13	.19	.26	.32	.39	.45	.51	.58	.64
1	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71
2	-.55	-.49	-.43	-.38	-.32	-.25	-.19	-.13	-.06	.00	.06	.13	.19	.25	.32	.38	.43	.49	.55	.60
3	.84	.87	.90	.93	.95	.97	.98	.99	1.00	1.00	1.00	.99	.98	.97	.95	.93	.90	.87	.84	.80
4	-.91	-.85	-.78	-.70	-.60	-.49	-.38	-.25	-.13	.00	.13	.25	.38	.49	.60	.70	.78	.85	.91	.96
5	.41	.52	.62	.72	.80	.87	.93	.97	.99	1.00	.99	.97	.93	.87	.80	.72	.62	.52	.41	.29
6	-.99	-1.00	-.98	-.91	-.82	-.70	-.55	-.38	-.19	.00	.19	.38	.55	.70	.82	.91	.98	1.00	.99	.94
7	-.16	.03	.22	.41	.57	.72	.84	.93	.98	1.00	.98	.93	.84	.72	.57	.41	.22	.03	-.16	-.34
8	-.74	-.89	-.98	-1.00	-.96	-.85	-.70	-.49	-.25	.00	.25	.49	.70	.85	.96	1.00	.98	.89	.74	.55
9	-.67	-.46	-.22	.03	.29	.52	.72	.87	.97	1.00	.97	.87	.72	.52	.29	.03	-.22	-.46	-.67	-.84
10	-.25	-.55	-.78	-.94	-1.00	-.96	-.82	-.60	-.32	.00	.32	.60	.82	.96	1.00	.94	.78	.55	.25	-.06
11	-.97	-.84	-.62	-.34	-.03	.29	.57	.80	.95	1.00	.95	.80	.57	.29	-.03	-.34	-.62	-.84	-.97	-1.00
12	.32	-.06	-.43	-.74	-.94	-1.00	-.91	-.70	-.38	.00	.38	.70	.91	1.00	.94	.74	.43	.06	-.32	-.65
13	-.95	-1.00	-.90	-.67	-.34	.03	.41	.72	.93	1.00	.93	.72	.41	.03	-.34	-.67	-.90	-1.00	-.95	-.76
14	.78	.43	.00	-.43	-.78	-.98	-.98	-.78	-.43	.00	.43	.78	.98	.98	.78	.43	.00	-.43	-.78	-.98
15	-.62	-.90	-1.00	-.90	-.62	-.22	.22	.62	.90	1.00	.90	.62	.22	-.22	-.62	-.90	-1.00	-.90	-.62	-.22
16	.99	.82	.43	-.06	-.55	-.89	-1.00	-.85	-.49	.00	.49	.85	1.00	.89	.55	.06	-.43	-.82	-.99	-.91
17	-.10	-.57	-.90	-1.00	-.84	-.46	.03	.52	.87	1.00	.87	.52	.03	-.46	-.84	-1.00	-.90	-.57	-.10	.41
18	.89	.99	.78	.32	-.25	-.74	-.99	-.91	-.55	.00	.55	.91	.99	.74	.25	-.32	-.78	-.99	-.89	-.49
19	.46	-.10	-.62	-.95	-.97	-.67	-.16	.41	.84	1.00	.84	.41	-.16	-.67	-.97	-.95	-.62	-.10	.46	.87
20	.49	.91	.98	.65	.06	-.55	-.94	-.96	-.60	.00	.60	.96	.94	.55	-.06	-.65	-.98	-.91	-.49	.13
21	.87	.41	-.22	-.76	-1.00	-.84	-.34	.29	.80	1.00	.80	.29	-.34	-.84	-1.00	-.76	-.22	.41	.87	.99
22	-.06	.60	.98	.89	.38	-.32	-.85	-.99	-.65	.00	.65	.99	.85	.32	-.38	-.89	-.98	-.60	.06	.70
23	1.00	.80	.22	-.46	-.93	-.95	-.52	.16	.76	1.00	.76	.16	-.52	-.95	-.93	-.46	.22	.80	1.00	.72
24	-.60	.13	.78	.99	.65	-.06	-.74	-1.00	-.70	.00	.70	1.00	.74	.06	-.65	-.99	-.78	-.13	.60	.99
25	.80	.99	.62	-.10	-.76	-1.00	-.67	.03	.72	1.00	.72	.03	-.67	-1.00	-.76	-.10	.62	.99	.80	.16
26	-.94	-.38	.43	.96	.85	.19	-.60	-.99	-.74	.00	.74	.99	.60	-.19	-.85	-.96	-.43	.38	.94	.89
27	.34	.93	.90	.29	-.52	-.98	-.80	-.10	.67	1.00	.67	-.10	-.80	-.98	-.52	.29	.90	.93	.34	-.46
28	-.98	-.78	.00	.78	.98	.43	-.43	-.98	-.78	.00	.78	.98	.43	-.43	-.98	-.78	.00	.78	.98	.43
29	-.22	.62	1.00	.62	-.22	-.90	-.90	-.22	.62	1.00	.62	-.22	-.90	-.90	-.22	.62	1.00	.62	-.22	-.90
30	-.70	-.99	-.43	.49	.99	.65	-.25	-.94	-.82	.00	.82	.94	.25	-.65	-.99	-.49	.43	.99	.70	-.19
31	-.72	.16	.90	.87	.10	-.76	-.97	-.34	.57	1.00	.57	-.34	-.97	-.76	.10	.87	.90	.16	-.72	-.98
32	-.19	-.94	-.78	.13	.91	.82	-.06	-.89	-.85	.00	.85	.89	.06	-.82	-.91	-.13	.78	.94	.19	-.74
33	-.98	-.34	.62	.99	.41	-.57	-1.00	-.46	.52	1.00	.52	-.46	-1.00	-.57	.41	.99	.62	-.34	-.98	-.67
34	.38	-.65	-.98	-.25	.74	.94	.13	-.82	-.89	.00	.89	.82	-.13	-.94	-.74	.25	.98	.65	-.38	-.99
35	-.93	-.76	.22	.97	.67	-.34	-.99	-.57	.46	1.00	.46	-.57	-.99	-.34	.67	.97	.22	-.76	-.93	-.10
36	.82	-.19	-.98	-.60	.49	.99	.32	-.74	-.91	.00	.91	.74	-.32	-.99	-.49	.60	.98	.19	-.82	-.85
37	-.57	-.98	-.22	.80	.87	-.10	-.95	-.67	.41	1.00	.41	-.67	-.95	-.10	.87	.80	-.22	-.98	-.57	.52
38	1.00	.32	-.78	-.85	.19	.99	.49	-.65	-.94	.00	.94	.65	-.49	-.99	-.19	.85	.78	-.32	-1.00	-.38
39	-.03	-.95	-.62	.52	.98	.16	-.87	-.76	.34	1.00	.34	-.76	-.87	.16	.98	.52	-.62	-.95	-.03	.93
40	.85	.74	-.43	-.99	-.13	.91	.65	-.55	-.96	.00	.96	.55	-.65	-.91	.13	.99	.43	-.74	-.85	.25
41	.52	-.67	-.90	.16	.99	.41	-.76	-.84	.29	1.00	.29	-.84	-.76	.41	.99	.16	-.90	-.67	.52	.97
42	.43	.98	.00	-.98	-.43	.78	.78	-.43	-.98	.00	.98	.43	-.78	-.78	.43	.98	.00	-.98	-.43	.78
43	.90	-.22	-1.00	-.22	.90	.62	-.62	-.90	.22	1.00	.22	-.90	-.62	.62	.90	-.22	-1.00	-.22	.90	.62
44	-.13	.96	.43	-.82	-.70	.60	.89	-.32	-.99	.00	.99	.32	-.89	-.60	.70	.82	-.43	-.96	.13	1.00
45	.99	.29	-.90	-.57	.72	.80	-.46	-.95	.16	1.00	.16	-.95	-.46	.80	.72	-.57	-.90	.29	.99	.03
46	-.65	.70	.78	-.55	-.89	.38	.96	-.19	-.99	.00	.99	.19	-.96	-.38	.89	.55	-.78	-.70	.65	.82
47	.76	.72	-.62	-.84	.46	.93	-.29	-.98	.10	1.00	.10	-.98	-.29	.93	.46	-.84	-.62	.72	.76	-.57
48	-.96	.25	.98	-.19	-.99	.13	.99	-.06	-1.00	.00	1.00	.06	-.99	-.13	.99	.19	-.98	-.25	.96	.32
49	.29	.97	-.22	-.98	.16	.99	-.10	-1.00	.03	1.00	.03	-1.00	-.10	.99	.16	-.98	-.22	.97	.29	-.95
50	-.96	-.25	.98	.19	-.99	-.13	.99	.06	-1.00	.00	1.00	-.06	-.99	.13	.99	-.19	-.98	.25	.96	-.32

TABLE OF LINEAR FUNCTIONS FOR ANDREWS PLOTTING METHOD

VALUES OF T

	.70	.77	.83	.90	.96	1.03	1.09	1.15	1.22	1.28	1.35	1.41	1.47	1.54	1.60	1.67	1.73	1.80	1.86	1.92
1	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71
2	.65	.70	.74	.78	.82	.85	.89	.91	.94	.96	.98	.99	.99	1.00	1.00	.99	.99	.98	.96	.94
3	.76	.72	.67	.62	.57	.52	.46	.41	.34	.29	.22	.16	.10	.03	-.03	-.10	-.16	-.22	-.29	-.34
4	.99	1.00	.99	.98	.94	.89	.82	.74	.65	.55	.43	.32	.19	.06	-.06	-.19	-.32	-.43	-.55	-.65
5	.16	.03	-.10	-.22	-.34	-.46	-.57	-.67	-.76	-.84	-.90	-.95	-.98	-1.00	-1.00	-.98	-.95	-.90	-.84	-.76
6	.85	.74	.60	.43	.25	.06	-.13	-.32	-.49	-.65	-.78	-.89	-.96	-.99	-.99	-.96	-.89	-.78	-.65	-.49
7	-.52	-.67	-.80	-.90	-.97	-1.00	-.99	-.95	-.87	-.76	-.62	-.46	-.29	-.10	.10	.29	.46	.62	.76	.87
8	.32	.06	-.19	-.43	-.65	-.82	-.94	-.99	-.99	-.91	-.78	-.60	-.38	-.13	.13	.38	.60	.78	.91	.99
9	-.95	-1.00	-.98	-.90	-.76	-.57	-.34	-.10	.16	.41	.62	.80	.93	.99	.99	.93	.80	.62	.41	.16
10	-.38	-.65	-.85	-.98	-.99	-.91	-.74	-.49	-.19	.13	.43	.70	.89	.99	.99	.89	.70	.43	.13	-.19
11	-.93	-.76	-.52	-.22	.10	.41	.67	.87	.98	.99	.90	.72	.46	.16	-.16	-.46	-.72	-.90	-.99	-.98
12	-.89	-.99	-.96	-.78	-.49	-.13	.25	.60	.85	.99	.98	.82	.55	.19	-.19	-.55	-.82	-.98	-.99	-.85
13	-.46	-.10	.29	.62	.87	.99	.97	.80	.52	.16	-.22	-.57	-.84	-.98	-.98	-.84	-.57	-.22	.16	.52
14	-.98	-.70	-.43	.00	.43	.78	.98	.98	.78	.43	.00	-.43	-.78	-.98	-.98	-.78	-.43	.00	.43	.78
15	.22	.62	.90	1.00	.90	.62	.22	-.22	-.62	-.90	-1.00	-.90	-.62	-.22	.22	.62	.90	1.00	.90	.62
16	-.60	-.13	.38	.78	.99	.94	.65	.19	-.32	-.74	-.98	-.96	-.70	-.25	.25	.70	.96	.98	.74	.32
17	.80	.99	.93	.62	.16	-.34	-.76	-.98	-.95	-.67	-.22	.29	.72	.97	.97	.72	.29	-.22	-.67	-.95
18	.06	.60	.94	.98	.70	.19	-.38	-.82	-1.00	-.85	-.43	.13	.65	.96	.96	.65	.13	-.43	-.85	-1.00
19	1.00	.80	.34	-.22	-.72	-.98	-.93	-.57	-.03	.52	.90	.99	.76	.29	-.29	-.76	-.99	-.90	-.52	.03
20	.70	.99	.89	.43	-.19	-.74	-.99	-.85	-.38	.25	.78	1.00	.82	.32	-.32	-.82	-1.00	-.78	-.25	.38
21	.72	.16	-.46	-.90	-.98	-.67	-.10	.52	.93	.97	.62	.03	-.57	-.95	-.95	-.57	.03	.62	.97	.93
22	.99	.82	.25	-.43	-.91	-.96	-.55	.13	.74	1.00	.78	.19	-.49	-.94	-.94	-.49	.19	.78	1.00	.74
23	.10	-.57	-.97	-.90	-.41	.29	.84	.99	.67	.03	-.62	-.98	-.87	-.34	.34	.87	.98	.62	-.03	-.67
24	.82	.19	-.55	-.98	-.85	-.25	.49	.96	.89	.32	-.43	-.94	-.91	-.38	.38	.91	.94	.43	-.32	-.89
25	-.57	-.98	-.84	-.22	.52	.97	.87	.29	-.46	-.95	-.90	-.34	.41	.93	.93	.41	-.34	-.90	-.95	-.46
26	.25	-.55	-.99	-.78	-.06	.70	1.00	.65	-.13	-.82	-.98	-.49	.32	.91	.91	.32	-.49	-.98	-.82	-.13
27	-.97	-.84	-.16	.62	1.00	.72	-.03	-.76	-.99	-.57	.22	.87	.95	.41	-.41	-.95	-.87	-.22	.57	.99
28	-.43	-.98	-.78	.00	.78	.98	.43	-.43	-.98	-.78	.00	.78	.98	.43	-.43	-.98	-.78	.00	.78	.98
29	-.90	-.22	.62	1.00	.62	-.22	-.90	-.90	-.22	.62	1.00	.62	-.22	-.90	-.90	-.22	.62	1.00	.62	-.22
30	-.91	-.85	-.06	.78	.96	.32	-.60	-1.00	-.55	.38	.98	.74	-.13	-.89	-.89	-.13	.74	.98	.38	-.55
31	-.41	.52	1.00	.62	-.29	-.95	-.80	.03	.84	.93	.22	-.67	-.99	-.46	.46	.99	.67	-.22	-.93	-.84
32	-.96	-.25	.70	.98	.32	-.65	-.99	-.38	.60	.99	.43	-.55	-1.00	-.49	.49	1.00	.55	-.43	-.99	-.60
33	.29	.97	.72	-.22	-.95	-.76	.16	.93	.80	-.10	-.90	-.84	.03	.87	.87	.03	-.84	-.90	-.10	.80
34	-.55	.49	1.00	.43	-.60	-.99	-.32	.70	.96	.19	-.78	-.91	-.06	.85	.85	-.06	-.91	-.78	.19	.96
35	.84	.87	-.03	-.90	-.80	.16	.95	.72	-.29	-.98	-.62	.41	1.00	.52	-.52	-1.00	-.41	.62	.98	.29
36	.13	.96	.65	-.43	-1.00	-.38	.70	.94	.06	-.89	-.78	.25	.99	.55	-.55	-.99	-.25	.78	.89	-.06
37	.99	.29	-.76	-.90	.03	.93	.72	-.34	-1.00	-.46	.62	.97	.16	-.84	-.84	.16	.97	.62	-.46	-1.00
38	.74	.89	-.13	-.98	-.55	.60	.96	.06	-.91	-.70	.43	.99	.25	-.82	-.82	.25	.99	.43	-.70	-.91
39	.67	-.46	-.99	-.22	.84	.80	-.29	-1.00	-.41	.72	.90	-.10	-.97	-.57	.57	.97	.10	-.90	-.72	.41
40	1.00	.32	-.82	-.78	.38	.99	.19	-.89	-.70	.49	.98	.06	-.94	-.60	.60	.94	-.06	-.98	-.49	.70
41	.03	-.95	-.57	.62	.93	-.10	-.98	-.46	.72	.87	-.22	-1.00	-.34	.80	.80	-.34	-1.00	-.22	.87	.72
42	.78	-.43	-.98	.00	.98	.43	-.78	-.78	.43	.98	.00	-.98	-.43	.78	.78	-.43	-.98	.00	.98	.43
43	-.62	-.90	.22	1.00	.22	-.90	-.62	.62	.90	-.22	-1.00	-.22	.90	.62	-.62	-.90	.22	1.00	.22	-.90
44	.19	-.94	-.49	.78	.74	-.55	-.91	.25	.99	.06	-.98	-.38	.85	.65	-.65	-.85	.38	.98	-.06	-.99
45	-.98	-.34	.87	.62	-.67	-.84	.41	.97	-.10	-1.00	-.22	.93	.52	-.76	-.76	.52	.93	-.22	-1.00	-.10
46	-.49	-.91	.32	.98	-.13	-1.00	-.06	.99	.25	-.94	-.43	.85	.60	-.74	-.74	.60	.85	-.43	-.94	.25
47	-.87	.41	.95	-.22	-.99	.03	1.00	.16	-.97	-.34	.90	.52	-.80	-.67	.67	.80	-.52	-.90	.34	.97
48	-.94	-.38	.91	.43	-.89	-.49	.85	.55	-.82	-.60	.78	.65	-.74	-.70	.70	.74	-.65	-.78	.60	.82
49	-.34	.93	.41	-.90	-.46	.87	.52	-.84	-.57	.80	.62	-.76	-.67	.72	.72	-.67	-.76	.62	.80	-.57
50	-.94	.38	.91	-.43	-.89	.49	.85	-.55	-.82	.60	.78	-.65	-.74	.70	.70	-.74	-.65	.78	.60	-.82

TABLE OF LINEAR FUNCTIONS FOR ANDREWS PLOTTING METHOD

VALUES OF T

	1.99	2.05	2.12	2.18	2.24	2.31	2.37	2.44	2.50	2.56	2.63	2.69	2.76	2.82	2.88	2.95	3.01	3.08	3.14
1	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71
2	.91	.89	.85	.82	.78	.74	.70	.65	.60	.55	.49	.43	.38	.32	.25	.19	.13	.06	.00
3	-.41	-.46	-.52	-.57	-.62	-.67	-.72	-.76	-.80	-.84	-.87	-.90	-.93	-.95	-.97	-.98	-.99	-1.00	-1.00
4	-.74	-.82	-.89	-.94	-.98	-.99	-1.00	-.99	-.96	-.91	-.85	-.78	-.70	-.60	-.49	-.38	-.25	-.13	.00
5	-.67	-.57	-.46	-.34	-.22	-.10	.03	.16	.29	.41	.52	.62	.72	.80	.87	.93	.97	.99	1.00
6	-.32	-.13	.06	.25	.43	.60	.74	.85	.94	.99	1.00	.98	.91	.82	.70	.55	.38	.19	.00
7	.95	.99	1.00	.97	.90	.80	.67	.52	.34	.16	-.03	-.22	-.41	-.57	-.72	-.84	-.93	-.98	-1.00
8	.99	.94	.82	.65	.43	.19	-.06	-.32	-.55	-.74	-.89	-.98	-1.00	-.96	-.85	-.70	-.49	-.25	.00
9	-.10	-.34	-.57	-.76	-.90	-.98	-1.00	-.95	-.84	-.67	-.46	-.22	.03	.29	.52	.72	.87	.97	1.00
10	-.49	-.74	-.91	-.99	-.98	-.85	-.65	-.38	-.06	.25	.55	.78	.94	1.00	.96	.82	.60	.32	.00
11	-.87	-.67	-.41	-.10	.22	.52	.76	.93	1.00	.97	.84	.62	.34	.03	-.29	-.57	-.80	-.95	-1.00
12	-.60	-.25	.13	.49	.78	.96	.99	.89	.65	.32	-.06	-.43	-.74	-.94	-1.00	-.91	-.70	-.38	.00
13	.80	.97	.99	.87	.62	.29	-.10	-.46	-.76	-.95	-1.00	-.90	-.67	-.34	.03	.41	.72	.93	1.00
14	.98	.98	.78	.43	.00	-.43	-.78	-.98	-.98	-.78	-.43	.00	.43	.78	.98	.98	.78	.43	.00
15	.22	-.22	-.62	-.90	-1.00	-.90	-.62	-.22	.22	.62	.90	1.00	.90	.62	.22	-.22	-.62	-.90	-1.00
16	-.19	-.65	-.94	-.99	-.78	-.38	.13	.60	.91	.99	.82	.43	-.06	-.55	-.89	-1.00	-.85	-.49	.00
17	-.98	-.76	-.34	.16	.62	.93	.99	.80	.41	-.10	-.57	-.90	-1.00	-.84	-.46	.03	.52	.87	1.00
18	-.82	-.38	.19	.70	.98	.94	.60	.06	-.49	-.89	-.99	-.78	-.32	.25	.74	.99	.91	.55	.00
19	.57	.93	.98	.72	.22	-.34	-.80	-1.00	-.87	-.46	.10	.62	.95	.97	.67	.16	-.41	-.84	-1.00
20	.85	.99	.74	.19	-.43	-.89	-.99	-.70	-.13	.49	.91	.98	.65	.06	-.55	-.94	-.96	-.80	.00
21	.52	-.10	-.67	-.98	-.90	-.46	.16	.72	.99	.87	.41	-.22	-.76	-1.00	-.84	-.34	.29	.80	1.00
22	.13	-.55	-.96	-.91	-.43	.25	.82	.99	.70	.06	-.80	-.98	-.89	-.38	.32	.85	.99	.65	.00
23	-.99	-.84	-.29	.41	.90	.97	.57	-.10	-.72	-1.00	-.80	-.22	.46	.93	.95	.52	-.16	-.76	-1.00
24	-.96	-.49	.25	.85	.98	.55	-.19	-.82	-.99	-.80	.13	.78	.99	.85	-.06	-.74	-1.00	-.70	.00
25	.29	.87	.97	.52	-.22	-.84	-.98	-.57	.16	.80	.99	.62	-.10	-.76	-1.00	-.67	.03	.72	1.00
26	.65	1.00	.70	-.06	-.78	-.99	-.55	.25	.89	.94	.38	-.43	-.96	-.85	-.19	.60	.99	.74	.00
27	.76	.03	-.72	-1.00	-.62	.16	.84	.97	.46	-.34	-.93	-.90	-.29	.52	.98	.80	.10	-.67	-1.00
28	.43	-.43	-.98	-.78	.00	.78	.98	.43	-.43	-.98	-.78	.00	.78	.98	.43	-.43	-.98	-.78	.00
29	-.90	-.90	-.22	.62	1.00	.62	-.22	-.90	-.90	-.22	.62	1.00	.62	-.22	-.90	-.90	-.22	.62	1.00
30	-1.00	-.60	.32	.96	.78	-.06	-.85	-.91	-.19	.70	.99	.43	-.49	-.99	-.65	.25	.94	.82	.00
31	-.03	.80	.95	.29	-.62	-1.00	-.52	.41	.98	.72	-.16	-.90	-.87	-.10	.76	.97	.34	-.57	-1.00
32	.38	.99	.65	-.32	-.98	-.70	.25	.96	.74	-.19	-.94	-.78	.13	.91	.82	-.06	-.89	-.85	.00
33	.93	.16	-.76	-.95	-.22	.72	.97	.29	-.67	-.98	-.34	.62	.99	.41	-.57	-1.00	-.46	.52	1.00
34	.70	-.32	-.99	-.60	.43	1.00	.49	-.55	-.99	-.38	.65	.98	.25	-.74	-.94	-.13	.82	.89	.00
35	-.72	-.95	-.16	.80	.90	.03	-.87	-.84	.10	.93	.76	-.22	-.97	-.67	.34	.99	.57	-.46	-1.00
36	-.94	-.70	.38	1.00	.43	-.65	-.96	-.13	.85	.82	-.19	-.98	-.60	.49	.99	.32	-.74	-.91	.00
37	-.34	.72	.93	.03	-.90	-.76	.29	.99	.52	-.57	-.98	-.22	.80	.87	-.10	-.95	-.67	.41	1.00
38	.06	.96	.60	-.55	-.98	-.13	.89	.74	-.38	-1.00	-.32	.78	.85	-.19	-.99	-.49	.65	.94	.00
39	1.00	.29	-.80	-.84	.22	.99	.46	-.67	-.93	.03	.95	.62	-.52	-.98	-.16	.87	.76	-.34	-1.00
40	.89	-.19	-.99	-.38	.78	.82	-.32	-1.00	-.25	.85	.74	-.43	-.99	-.13	.91	.65	-.55	-.96	.00
41	-.46	-.98	-.10	.93	.62	-.57	-.95	.03	.97	.52	-.67	-.90	.16	.99	.41	-.76	-.84	.29	1.00
42	-.78	.78	-.43	-.98	.00	.98	.43	-.78	-.78	.43	-.97	.00	.97	.43	-.78	-.78	.43	.97	.00
43	-.62	.62	.90	-.22	-1.00	-.22	.90	.62	-.62	-.90	.22	1.00	.22	-.90	-.62	.62	.90	-.22	-1.00
44	-.25	.91	.55	-.74	-.78	.49	.94	-.19	-1.00	-.13	.96	.43	-.82	-.70	.60	.89	-.32	-.99	.00
45	.97	.41	-.84	-.67	.62	.87	-.34	-.98	.03	.99	.29	-.90	-.57	.72	.80	-.46	-.95	.16	1.00
46	.99	-.06	-1.00	-.13	.96	.32	-.91	-.49	.82	.65	-.70	-.78	.55	.89	-.38	-.96	.19	.99	.00
47	-.16	-1.00	-.03	.99	.22	-.95	-.41	.87	.57	-.76	-.72	.62	.84	-.46	-.93	.29	.98	-.10	-1.00
48	-.55	-.85	.49	.89	-.43	-.91	.38	.94	-.32	-.96	.25	.98	-.19	-.99	.13	.99	-.06	-1.00	.00
49	-.84	.52	.87	-.46	-.90	.41	.93	-.34	-.95	.29	.97	-.22	-.98	.16	.99	-.10	-1.00	.03	1.00
50	-.55	.85	.49	-.89	-.43	.91	.38	-.94	-.32	.96	.25	-.98	-.19	.99	.13	-.99	-.06	1.00	.00

Nance, W. L., B. H. Polmer, and G. C. Keith

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INSECTS
and
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COTTONWOOD

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INSECTS AND DISEASES OF COTTONWOOD

R. C. Morris, T. H. Filer, J. D. Solomon,
F. I. McCracken, N. A. Overgaard, and M. J. Weiss[1]

Insects and disease organisms are a continuing threat to cottonwood *(Populus deltoides* Bartr.), especially during the tree's first 5 years. The danger is intensified in large plantings of a single species and age because rapid buildup of damaging agents can occur. This booklet will help forest nurserymen and plantation managers identify and control pest problems. The major insects and diseases are illustrated; and information on their importance, signs of infestation, biology, and natural control is presented. Brief mention is made of other pests which may be of local or sporadic concern.

A list of registered chemical controls is also provided. This list is subject to change as new materials are approved, and revisions will be made available at periodic intervals.

For further information, contact your State forester, county agent, or the nearest office of State and Private Forestry, U. S. Forest Service.

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[1] Morris, Filer, Solomon, and McCracken are stationed at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Mississippi, by the Southern Forest Experiment Station in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group. Overgaard and Weiss are members of the Forest Pest Management Group, Southeastern Area, State and Private Forestry.

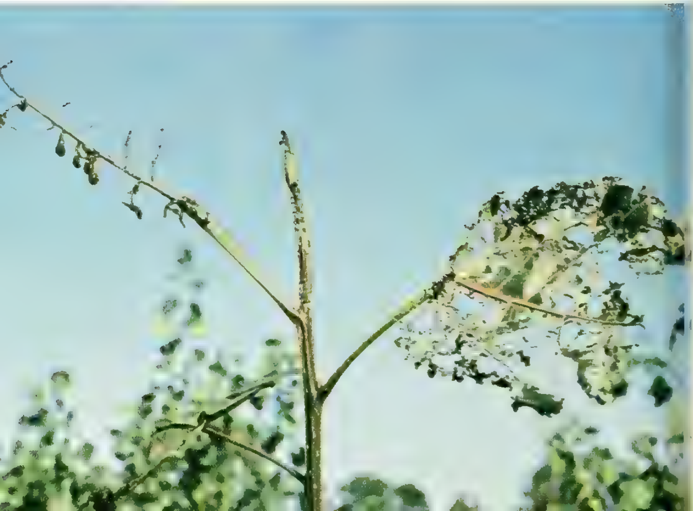
COTTONWOOD LEAF BEETLE

Chrysomela scripta F.

The cottonwood leaf beetle is one of the most serious pests of young trees in nurseries and plantations and occasionally causes severe damage in natural stands. In the nursery, the insect stunts height growth and reduces the yield of cuttings. First- and second-year plantations are weakened by early defoliation and may be overtopped by weeds. Continuing partial defoliation through the summer reduces tree growth and vigor. Serious damage occurs at the end of the growing season when heavy populations feed on terminal tissues and buds, killing as much as 10 inches (25 cm) of the terminals. Lateral buds sprout below the injured terminals, and branches may grow above the dead terminal even before the season ends. These branches grow rapidly the next year, resulting in multiple-forked tops that have little potential for the production of quality wood for logs and pulpwood.

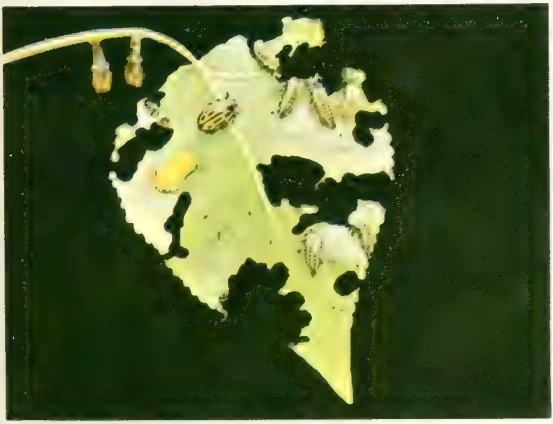
Often the sudden appearance of ragged foliage near branch ends and terminals of young cottonwoods will announce a leaf beetle attack. Some leaves will have brown patches where young larvae ate the green tissues. On other leaves, only the veins and midrib will remain. Heavy damage results in dead, black terminals from which the leaves and tissues are eaten. Other signs of the leaf beetle are black droppings on leaves and the unmistak-

Terminal killed by cottonwood leaf beetle.



able, pungent odor the larvae release when disturbed.

Adult beetles are oval, yellow, and about ¼ inch (6 mm) long with slender black markings on their wing covers. Egg clusters are bright yellow, and newly hatched larvae are black. As they develop, they turn brown, and prominent white scent gland spots appear along their sides.



Cottonwood leaf beetles.

Adults spend the winter under fallen leaf debris or in clumps of weeds. In early spring they emerge and feed on unfolding leaves or on tender bark at the tips of twigs. The female lays a cluster of 15 to 75 eggs on the undersides of leaves. The newly hatched larvae feed side by side and skeletonize the leaves. Older larvae feed separately and consume the entire leaf except for the larger veins. At maturity they attach themselves to leaves, bark, or to weeds and grass beneath the trees to pupate. In 5 to 10 days they emerge as adult beetles. There are several generations per year, each lasting about 35 days.

The spring generation of the leaf beetle may be greatly reduced by the red lady beetle *Coleomagilla maculata*, which feeds on the eggs and pupae. However, as the season progresses, the ladybugs disperse to feed on aphids and other prey and do not affect later broods of leaf beetles. Several predaceous bugs feed on leaf beetle larvae, and a parasitic wasp also attacks them. Effective chemical controls are available.

COTTONWOOD TWIG BORER

Gypsonoma haimbachiana Kft.

The cottonwood twig borer, one of the mos destructive insects of young trees, occurs through out the host species' range from Ontario to th Gulf of Mexico and west to the Great Plains. Larva feeding in the terminal tissues prevents norma elongation and may kill the growing tip. Th stunted terminals are rapidly overtopped by vig orous, undamaged laterals, resulting in a tree to with two to six forks. Later, one fork may asser dominance and become a new terminal, but a croo usually develops where the new terminal origin ates. Heavily damaged trees may be stag-heade bushes of little value.

Stunted terminals and short brown tubes of sil and borings near leaf bases indicate twig bore damage. Lateral branches overtop the termina which persists as a short stub in the forked to Small, red swollen areas along leaf veins and mid ribs show where newly hatched larvae fed in th

Twig borer damage in 3-year-old tree.

vein tissues before molting and entering the branch and terminal tips.

Adults moths are ash grey and have a wingspan of ½ inch (12 mm). The forewing has a dark grey base and a dark spot on its outer tip. Full-grown larvae are ½ inch (12 mm) long and pale in color with a brown head.

Brown frass tubes at borer entrances.

Moths emerge from cocoons in April or May. Females deposit eggs singly or in small groups on the upper surface of leaves along the midrib and veins. Newly hatched caterpillars feed in the midrib or vein until their first molt, then move to the base of the first developing leaf and tunnel into the tender shoot. When they are fully grown, they move down the trunk and spin thin cocoons in bark crevices or in litter under the trees.

Successive generations—as many as five in Mississippi—develop through the summer; and with each generation the twig borer population increases. By September there may be 20 or more larvae of 4 different ages in a 15-inch (38-cm) cottonwood terminal. Winter is spent as tiny second-stage larvae in shelters of silk and trash in old entrance scars near branch ends, under corky ridges below leaf bases, or near leaf buds. In spring the small larvae migrate to the new shoots and complete their growth.

Natural controls of the twig borer include the potter wasp (*Eumenes* sp.), which preys on larvae, and other parasites and predators of the eggs, larvae, and pupae. These are inadequate for protecting nurseries and plantations from serious economic loss; therefore, chemical controls may be needed.

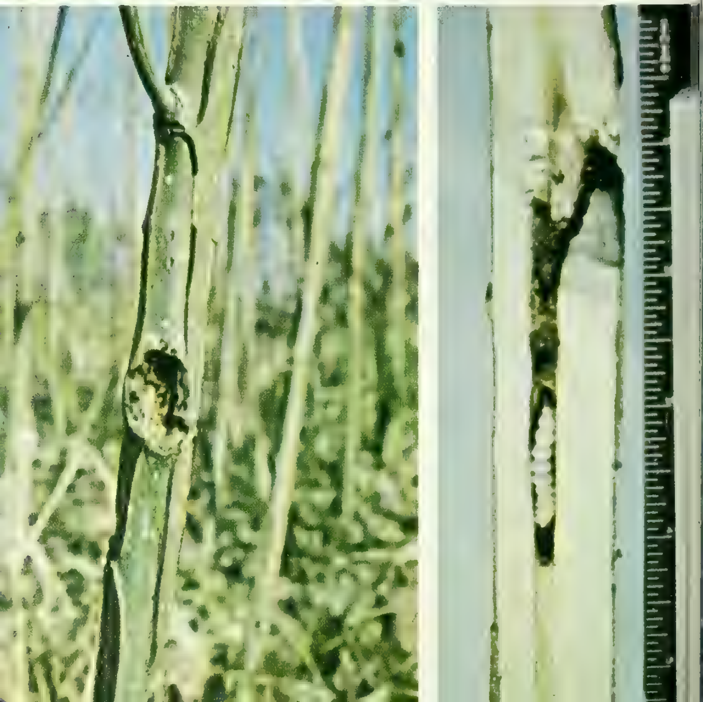
CLEARWING BORERS

Paranthrene dollii dollii (Neum.) and *P. tricincta* (Harris)

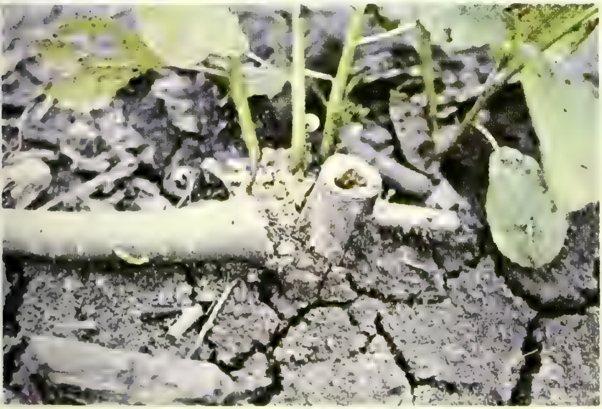
Two clearwing borers prevalent in the Southern United States cause serious losses in cottonwood plantations and nurseries. *P. dollii* damages the tree base, and weakened trees may break off at the ground. *P. tricincta* attacks terminals, and breakage can occur at the entrance hole 18 to 24 inches (45 to 60 cm) below the terminal tip. The borer holes also provide infection sites for stem canker diseases caused by a complex of fungi.

Nursery plants become infested during their first year. Populations build up during the second and third years in the stools left after cuttings are harvested. Heavily infested stools cannot support vigorous growth from sprouts, and large stems break off and die before cuttings are harvested Borer attacks also develop in the basal third of the shoots, and cuttings made from this material are rejected. As many as 10 percent of the cuttings produced may be damaged and discarded.

Clearwing borer, entrance (left) and stem sectioned to show larva and gallery (right).



Early signs of clearwing attack are sap flow from entrance holes and borings (frass) pushed out by the caterpillar. These signs will appear at the base of young trees infested by *P. dollii* or about a foot below the tip of terminals and branches attacked by *P. tricincta*. As the larvae grow, their galleries enlarge, and piles of frass accumulate at the tree base. A swelling of the stem may indicate the presence of *P. tricincta* in a terminal. When the terminal breaks off, the borer will be in the stub below the break. Evidences of adult emergence are brown pupal skins protruding from the exit holes. Infested trees will be drilled by woodpeckers feeding on the caterpillars during the winter.



Borer damage and frass at base of young cottonwood.

The adult of *P. dollii dollii* has narrow, dark brown forewings and partly transparent hindwings. Its wingspan is about 1¼ inches (32 mm). The body is brown, and orange crossbands bordered with yellow and dark brown mark the thorax and abdomen. The eggs are dark brown and oval. White to pinkish larvae with brown heads attain a final length of 1 to 1¼ inches (25 to 32 mm).

The adult *P. tricincta* has blue-black forewings, nearly transparent hindwings, a black body with three lemon yellow crossbands in the female and two in the male, and a wingspread of about 1 inch (25 mm).

The life cycles of both species are similar. The female lays eggs in bark crevices, especially near trunk scars. The larvae molt fives times while tunneling in the wood and pith and then prepare pupal cells at the gallery ends. Larvae overwinter in the galleries and pupate in early spring. Adults emerge in April, leaving the empty pupal skins protruding from their exit holes. Adult emergence peaks again in August, indicating two generations per year. There is, however, considerable overlapping; and larvae of several stages can be found in the trees during the late summer and fall.

Control.—There are no effective natural controls. Woodpecker predation reduces populations in nurseries and plantations but may aggrevate the damage by providing oviposition sites and additional entries for canker fungi. Sanitation measures in nurseries, especially burning infested cull stems, tips, and stools, will help hold down borer populations. Control chemicals are listed in the insert.

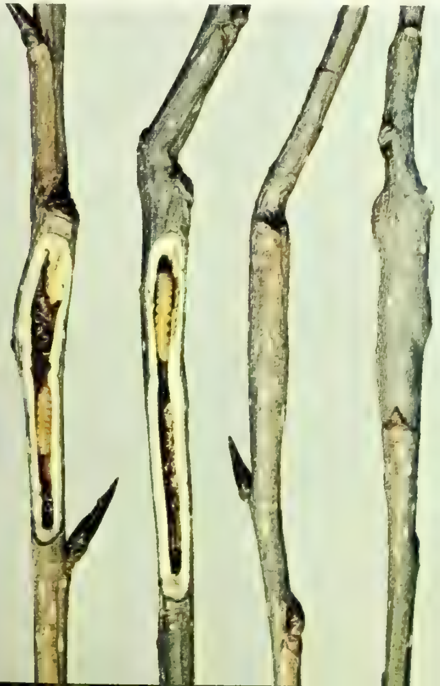
BRANCH BORERS

Oberea schaumii LeConte and *O. Delongi* Knull

Two branch borers attack cottonwood and other poplars throughout much of the United States. Although both species may occur together, *O. delongi* is more prevalent in the South, and *O. schaumii* is more common further north. Small stems and branches are tunneled and sometimes weakened so that breakage occurs. Terminal breakage often results in crooked trunks, forking, and heavy branching.

Egg niches, the earliest signs of attack, may remain in evidence on stems and branches for several weeks. Later, frass protrudes from the entrance, particularly during attacks of *O. schaumii; O. delongi* ejects little frass. Infested stems may appear swollen. This symptom is most noticeable with *O. delongi*, which causes some stems to become greatly enlarged and gall-like. The adults typically feed on the midribs and branch veins of the leaves; such feeding is conspicuous and indicates stem infestation.

Oberea delongi **attacks in cottonwood branches.**



O. delongi **adult feeding on cottonwood.**

The adults are elongate long-horn beetles. *O. schaumii* ranges from ½ to ⅝ inch (12 to 16 mm) in length; *O. delongi* is slightly smaller. Both species are variable in coloration. In *O. schaumii* the thorax is yellowish to orange with four dark, smooth spots; the wing covers vary from yellowish to black. In *O. delongi* the thorax varies from yellowish orange to black, and the wing covers are black. The larvae of both species are legless, narrow, and yellowish white. Larvae of *O. schaumii* reach a length of ½ to 1 inch (12 to 25 mm); those of *O. delongi* reach ⅜ to ⅝ inch (10 to 16 mm). The pupae of both species are yellowish white.

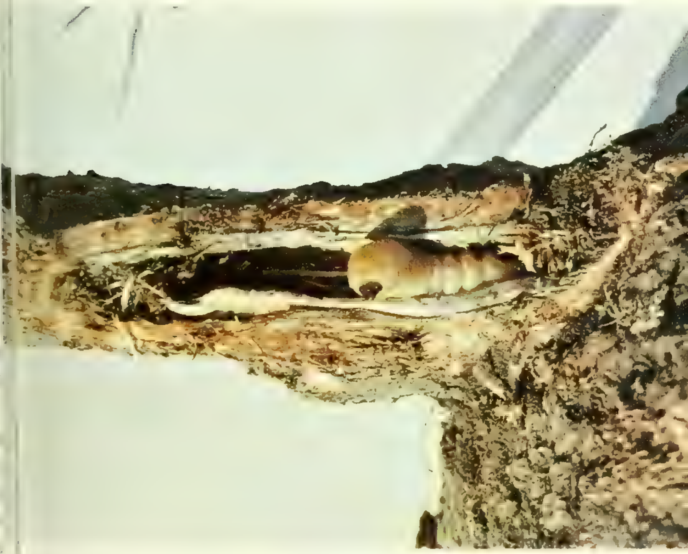
Adult beetles emerge from April to June and feed on the foliage before laying eggs in niches gnawed in the bark. *O. schaumii* selects stems and branches up to 1½ inches (38 mm) in diameter, but *O. delongi* prefers smaller stems (usually current year's growth) up to ½ inch (12 mm) in diameter. The eggs hatch in about 2 weeks, and the larvae begin tunneling down the center of the stem. Pupation occurs within the gallery. Adults cut circular holes to exit. The life cycle of *O. schaumii* varies from 1 to 3 years; that of *O. delongi* is 1 year.

Branch borer damage is usually kept at low levels by natural enemies. Woodpeckers, particularly downy woodpeckers, have been observed to destroy large numbers of *O. delongi* larvae in some stands. Larval diseases kill many borers during some years.

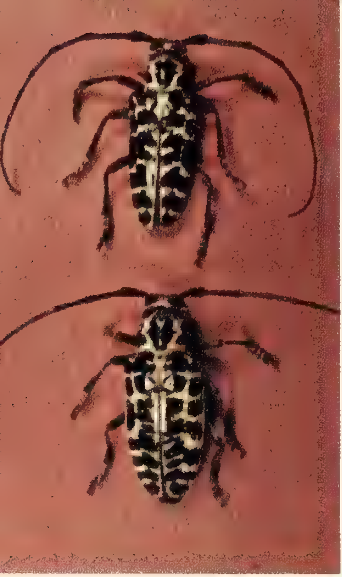
COTTONWOOD BORER
Plectrodera scalator (Fab.)

The cottonwood borer is a pest throughout the Southeastern States. It attacks the root collar and main roots. Young trees may be girdled or so structurally weakened that breakage occurs. Severe damage has been observed in young natural stands growing on sandy soils along the Mississippi River.

Light brown, fibrous frass is sometimes ejected from bark openings at or slightly above the ground line and accumulates in piles at the base of the tree. But since most attacks occur at or below the ground line and most larvae tunnel downward, infestations often go unnoticed unless breakage occurs. However, when the soil is removed from the root collar and shallow roots, wounds filled with protruding frass can be found in the bark. Also, because of their large size and conspicuous color, the adult beetles are easily spotted while feeding and ovipositing during the summer.



Lateral root with larva and gallery of cottonwood borer.



Adult cottonwood borer.

The adult is a large, robust, long-horn beetle ranging from 1 to 1½ inches (25 to 38 mm) in length and ⅜ to ½ inch (10 to 12 mm) in width. The body is black with white cross-stripes. A strong spine is located on each side. The antennae are about as long as the body in the female and slightly longer in the male. The eggs are elliptical, white, and about ⅛ inch (3 mm) long. The larvae are legless, elongate, moderately robust, and yellowish white; they reach a maximum length of 1¼ to 1½ inches (32 to 38 mm).

Adult beetles emerge during late spring and summer and begin feeding on the bark of tender cottonwood shoots. To oviposit, the female digs away the soil at the base of the tree to a depth of ⅜ inch (10 mm) or more, cuts a niche in the bark, and deposits one or more eggs. Upon hatching, the larvae mine downward in the inner bark, later tunneling into the wood. Taproots of small trees may be completely hollowed. In large trees, some larvae excavate irregular cavities and others produce long tunnels. Portions of the mines or galleries may be packed with excelsior-like frass. Pupation occurs within the gallery. The new adult chews through the pupal chamber and digs its way to the soil surface to escape. A life cycle is completed in 2 years.

Since most grubs are below the ground line, they are well protected from both predators and parasites. Woodpeckers capture a few larvae exposed above the ground line. Although a fungus disease has been found, it does not appear to be common. Extended flooding will kill many larvae. Damage can usually be kept to a minimum by planting on good sites and utilizing cultural practices that maintain a vigorous, healthy stand.

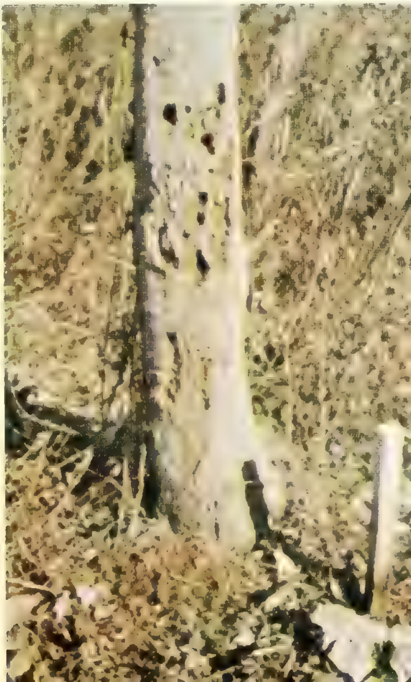
POPLAR BORER

Saperda calcarata Say

The poplar borer is a serious pest of cottonwood and other poplars throughout the United States and Canada. It attacks the trunks of trees 3 years and older. Clusters of larvae tunneling close together may riddle portions of the trunk. Woodpecker excavations and decay fungi further weaken damaged stems. Badly infested trees may be so structurally weakened that wind breakage occurs. The value of infested trees sawn for lumber may be greatly reduced.

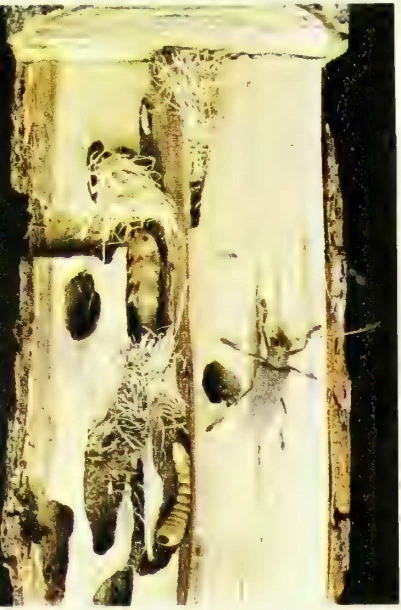
The most conspicuous early sign of attack is the appearance of sap spots on the trunk. Later, oozing sap mixed with fine frass is extruded through small openings in the bark. Although attacks may occur singly, they are typically clustered. After the bark is mined by a cluster of larvae, it begins to split or break irregularly as radial growth progresses. As the larvae grow, the frass becomes fibrous and excelsior-like. Coarse frass is usually conspicuous in large quantities at gallery entrances, lodged in bark crevices, and in piles around the base of the tree. Woodpeckers frequently excavate several holes in the wood and remove much of the loose bark in the vicinity of a larval cluster. Scars resulting from overgrown attacks remain for several years.

Trunk attacked by poplar borers. Note frass on ground and woodpecker holes above attack area.



The adult is a long-horn beetle, elongate, moderately robust, and ranges from ⅞ to 1⅛ inches (22 to 30 mm) in length. The body is grayish blue and heavily stippled with fine brown dots and yellowish spots. The antennae are about as long as the body. The eggs are slender, creamy white, and about ⅛ inch (3 mm) long. The larvae are legless, elongate, cylindrical, yellowish white, and 1⅛ to 1⅜ inches (30 to 35 mm) long. The pupae are yellowish white.

Adult beetles appear during late spring and early summer. After feeding on the tender shoots of young cottonwood they mate and begin laying eggs in niches cut in the bark. Eggs hatch in 2 to 3 weeks, and the larvae begin mining beneath the bark. Later, they tunnel into the sapwood and heartwood and produce extensive galleries. The larvae overwinter behind frass plugs within the galleries. The pupal stage lasts 2 to 3 weeks. The new adults exit through the gallery entrances. Two years are required for the life cycle.



Poplar borer in sectioned cottonwood trunk.

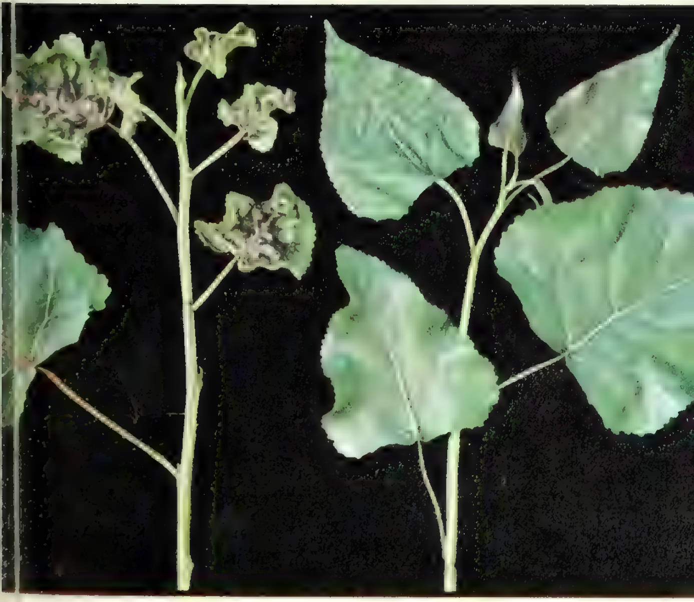
Parasites, predators, and disease help keep infestations in check. Considerable natural mortality also occurs among eggs and early instars because of heavy sap flow, which is enhanced by high soil moisture and tree vigor. Woodpeckers destroy many grubs in some stands and are probably the most important natural enemy once the larvae have established galleries in the wood. Brood trees, scarred by repeated attacks and harboring heavy populations of borers, should be removed to prevent or reduce spread to uninfested trees.

COTTONWOOD LEAF CURL MITE

Aculus lobulifera Keifer

Attacks by leaf curl mites seriously reduce growth and vigor of young cottonwoods in nurseries and plantations. Mites feed on terminal foliage and stems, causing stunting and malformation of leaves, terminal tips and buds as well as the loss of immature foliage. The pest has been observed in cottonwood throughout most of its commercial range.

Leaf damage symptoms appear in early summer and intensify as the hot, dry weather continues. Heavily attacked leaves become stunted with red veins and crinkled, purplish-green blades, which are brittle and curled. The petioles become scaly and brown. Terminal shoots are also stunted, scaly, and brown. Small, developing leaves commonly break off, leaving several inches of the terminal shoot leafless.



Typical foliage and stem damage by leaf curl mites. Normal foliage on the right.

Leaf curl mites are minute, four-legged, and straw-colored; they look like dust flecks on the leaves. They develop two alternating forms: hibernating mites and foliage-feeding mites, the primary form. The majority of the mites perish with leaf fall; but a few find hibernation shelters in bark crevices, branch scars, and at the base of the trunk. Early the next spring, the hibernating mites leave their shelters, feed on green tissues, and lay eggs, which produce primary forms on the new foliage. The primary mites multiply rapidly; and all stages, eggs to adults, are found together on the foliage and tender terminals. Heavy populations develop during dry periods, especially from June through August and in October.

Heavy rains disseminate mite populations, and new growth with normal foliage may follow; however, this pest may reappear with dry weather in the fall. No other natural controls are known. Some improved cottonwood clones show evidence of possible resistance, and these are being investigated further. Artificial controls are available and may reduce populations significantly.

VICEROY BUTTERFLY

Limentis archippus (Cramer)

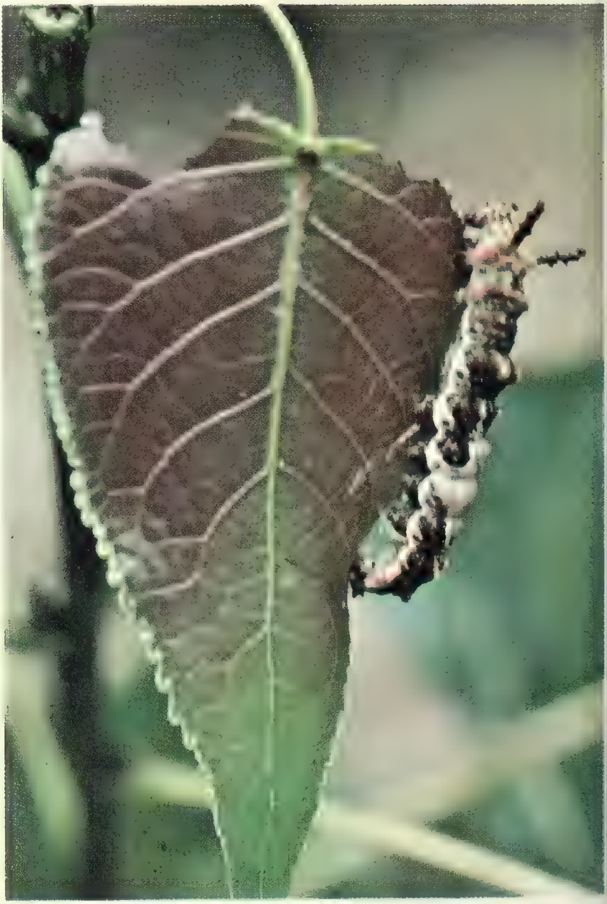
The viceroy butterfly is a common defoliator in cottonwood plantations throughout the United States. During most of the growing season, caterpillars feeding on leaves are of little concern; but later when few new leaves are being formed, caterpillars eat tender terminal tissues and buds, killing 8 to 10 inches (20 to 25 cm) of the terminals. New growth from lateral buds results in multiple-forked crowns the next year. These malformed trees will produce less pulpwood, saw logs, and veneer than healthy trees. The viceroy is normally not a serious pest in nurseries.

The first signs of attack are caterpillars on ragged, partly eaten leaves near branch ends. Late in the season, damaged terminals turn black and die. During the winter, leaf petioles fastened to the branch by silk will have small tubes of rolled leaf blade in which small caterpillars are hibernating.

The orange and black adult resembles the monarch butterfly but is smaller. It has a narrow black line across the hindwings and one row of white spots in the black marginal band of the wings. The full-grown caterpillar is about 1½ inches (38 mm) long and has a large, bilobed, pale green head. The body is olive green and white or brown and white. Two barbed, club-shaped, brown tubercles on the thorax are topped by two smaller tubercles armed with spines.

Eggs are laid on the leaves. The solitary caterpillars each consume several leaves during their growth. The full-grown larva secures itself to a leaf stem or branch and changes to a shiny brown and white chrysalis (pupa) from which the adult butterfly emerges after a few days. Two generations per year are recorded, but more may occur in the deep South.

In late fall, a small caterpillar fastens a leaf petiole to the branch with silk and then cuts away all but the base of the leaf blade. This part of the blade is rolled and fastened into a short tube in



Larva of viceroy butterfly.

which the ½-inch (12 mm) long caterpillar spends the winter. In spring, the caterpillar emerges and feeds on new leaves.

No natural controls are known.

POPLAR TENTMAKER
Ichthyura inclusa Hbn.

The poplar tentmaker occurs from southern Canada to the Gulf of Mexico and west to Colorado. It may seriously defoliate young trees in nurseries and plantations, especially during the first year. Height growth is stunted, resulting in fewer cuttings from nursery stock. Stunted plantation trees may be overtopped by weeds.

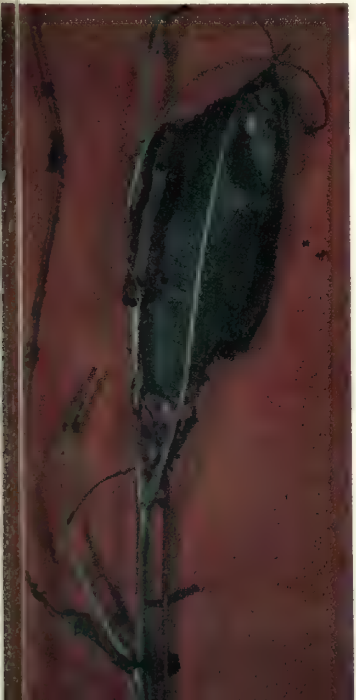
Attacks are announced by the presence of tents made of one or more leaves lined with silk and harboring the caterpillars.

Brownish-grey adult moths have three white lines across each forewing and a crest of brown hairs on the thorax. The wingspread is about 1 inch (25 mm). Caterpillars are dark brown with four yellow lines on the back and a bright yellow line on each side. They reach 1½ inches (38 mm) in length when fully grown and have black tubercles on the first and eighth abdominal segments.

There are two or more generations in the South. Adults appear in the spring and again in midsummer. Eggs are laid in clusters on the undersides of leaves. The larvae feed from May to October, then crawl to the ground and pupate in loose cocoons during the winter.

Parasites and predators usually control tentmakers in natural stands, but rapid build-ups can occur in plantations before the problem is recognized

Larva of poplar tentmaker and tent on cottonwood leaf.
(Picture courtesy of R. F. Anderson, Duke University.)



LEAFHOPPERS

Cicadellidae homalodisca coagulata (Say), *Oncometopia orbona* (Fab.), *Cuerna costalis* (Fab.), and *Aulacizes irrorata* (Fab.)

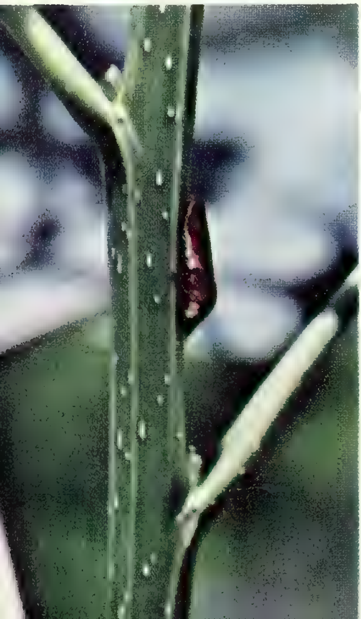
Four species of large leafhoppers injure young cottonwood trees by piercing plant tissues with their mouth parts and sucking the juices. Heavy feeding removes large quantities of sap from the trees, and this loss of sap can be especially harmful during dry periods in midsummer, when foliage is heavy. In addition, three of the four leafhoppers are known vectors of the virus causing Phony Peach Disease and may carry other viruses to cottonwoods.

There is an obvious sign of leafhopper activity: leaves below the feeding sites may be wet by fluid squirted from the leafhoppers.

Adult leafhoppers are about ½ inch (12 mm) long, bullet-shaped, and have strong jumping legs. The two species most common in midsummer are *H. coagulata*, which is brown, and *O. orbona*, which is blue with orange markings.

All four species spend the winter as adults or occasionally as nymphs under trash and debris in woodlands and along ditchbanks. In spring they become active, leave the woods, and feed on a variety of plants. Later they move to preferred herbaceous plants. Females lay eggs in clusters between the upper and lower leaf surfaces. The nymphs feed on various hosts during their development through five stages to the adult form.

No natural controls are known, but there are some approved chemical controls.



Homalodisca coagulata **on cottonwood terminal.**

OTHER INSECTS

The pests described below are usually not serious threats to cottonwoods. However, large populations occasionally build up in limited areas or on individual trees and cause considerable damage. Normally natural controls are sufficient, but to suppress periodic buildups in localized areas, artificial controls may be required.

The first four insects are moths. The adults are inconspicuous and do no damage, but the larvae feed on cottonwood.

Blotch leafminers, Paraleucoptera albella.—This insect probably occurs throughout the commercial range of cottonwood. Eggs are laid in clusters of 3 to 12 on the upper leaf surface. Groups of small, white larvae tunneling between the upper and lower leaf surfaces consume the green tissues and cause conspicuous brown blotches. Periodic heavy infestations may destroy half the total leaf surface and reduce growth of young cottonwoods. Full-grown larvae leave the mine and spin small white tent cocoons at leaf margins.

Serpentine leafminers, Gracillariidae.—The tiny, flat larvae construct winding mines in leaf blades and consume the green tissues. Their attacks late in the season are often noted, but their damage is usually negligible. Mature larvae spin small, flat-topped, white cocoons in curved leaf margins.

Leaf rollers, Tortricidae.—Pale green larvae about ¼ inch (6 mm) long fold over leaf margins and tips, fastening the edges with silk to form shelters in which they feed. Late in the season, new leaves may be conspicuously attacked, but damage to the tree is minor.

Epidermal miner, Marmara sp.—Tiny larvae mine immediately beneath the epidermis in phloem tissues and do not damage cambium or xylem. Larval mines appear as meandering brown lines on the smooth bark of 1- to 2-year-old trunks and branches. The injury is probably insignificant, but its presence can cause rejection of cuttings subject to quarantine examination for shipment.

Aphids or plant lice (Aphididae).—These small sucking insects are widely distributed and often cause local damage. Most forms suck the sap from leaves and tender terminal tissues. While feeding, they exude droplets of honeydew, which attract ants. Sooty mildew develops on leaves and tips covered with honeydew, and serious growth retardation may result. Other aphids feed on bark in the spring, injuring the bark and cambium. Others cause the formation of galls on leaf petioles, where they are feeding, and may cause premature leaf fall.

Night-feeding leaf beetles, Metachroma sp.—These beetles appear sporadically and can damage new plantings by killing tender new leaves, terminal tips, and buds. Adults are brown and smaller than cottonwood leaf beetles. In Mississippi they appear after mid-May and disappear after mid-June. They hide during the day and feed at night, cutting many small holes in the leaves. Older leaves remain, but new leaves turn black and drop off; terminal tips also turn black and die. The larvae are root feeders, and little is known of their biology.

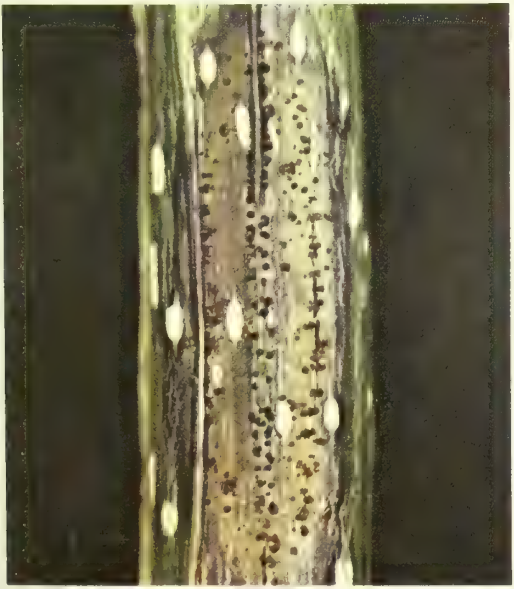
Leaf curl midge, Prodiplosis morrisi Gagne.—Maggots of a fly midge feed in the tightly rolled margins of developing cottonwood leaves and damage the tender tissues, causing them to turn black and die. The leaves cannot develop and usually drop off. Some may appear stunted and crinkled, with only their tips developed normally. Attacks typically occur in June and can slow the growth of first-year plantings. Heavy rains reduce outbreaks, and normal foliage development follows.

A host of other insects also attacks cottonwoods. Most are inoccuous and appear infrequently. Some are capable of building to damaging levels in large plantings. Such outbreaks can occur without warning and should be reported promptly so that potential damage can be anticipated and minimized.

CANKER DISEASES

Canker diseases cause losses of about 20 percent during the first season in plantations established with unrooted cottonwood cuttings. Cankers are most severe on poor sites and under conditions of environmental stress.

Septoria musiva Peck. is considered the pioneer organism. *Fusarium solani* (Mart) Snyder & Hans., *Cytospora chrysosperma* Fr., *Phomopsis macrospora* Kobayshi & Chiba, and *Botryodiplodia theobromae* Pat. usually invade the small Septoria cankers. Although these fungi are secondary in the ecological succession, they singly or collectively cause mortality.



Septoria stem canker on young cottonwood.

The four fungi are indigenous to most areas and can infect nursery stock by means of wind-borne spores. They overwinter as mycelia or spores on cottonwood cuttings stored for spring planting. No fruiting structures are associated with *F. solani*.

Phomopsis macrospora **producing tiny, yellow strings of spores.**

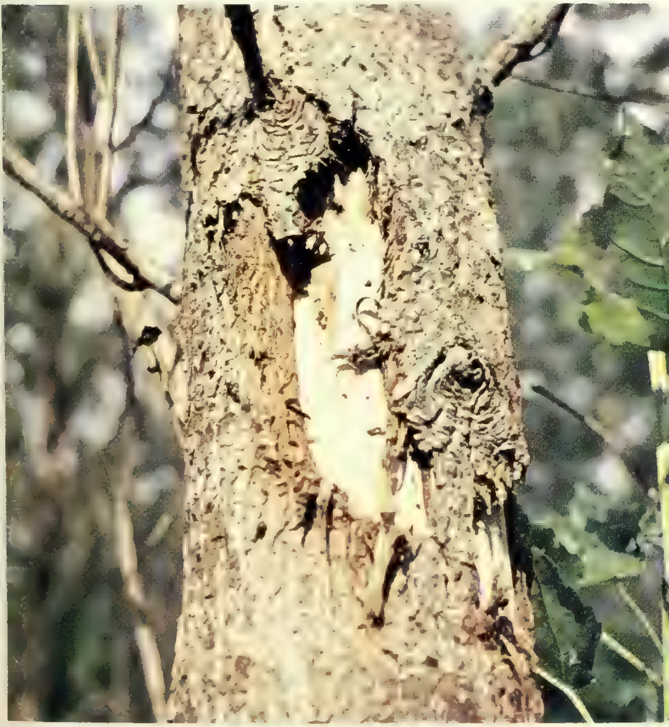
The other three fungi produce inconspicuous, tiny, flask-shaped fruiting structures, which protrude through the epidermis and produce numerous spores. When these infected cuttings are planted, they may leaf-out and appear healthy; but many die before developing a root system. Mortality is increased by enviornmental conditions that limit plant growth or cause plant stress.

Inoculum enters older trees through wounds or insect borings. Cankers on stems of 2- and 3-year-old trees are easily detected. They usually develop in fall and by spring are 3 to 6 inches (7.5 to 15 cm) in diameter. On vigorous trees, cankers are arrested during the growing season and usually callus over. On slow-growing trees, cankers can girdle the stem, and leaves above the cankers will wilt but do not drop until late summer. The stem below the cankers may remain green until fall when it dies back to the root crown. Often such trees develop root sprouts the following spring.

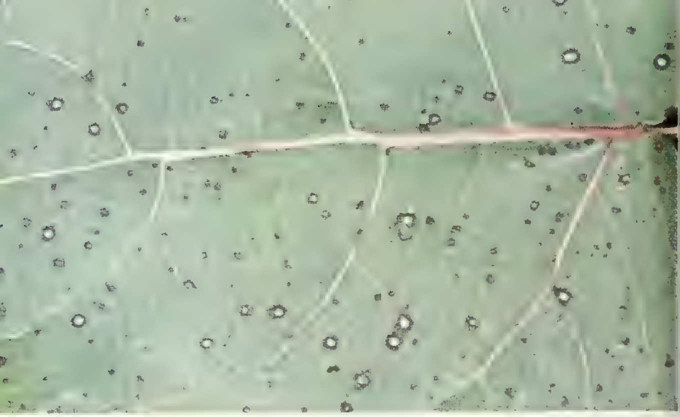
Cytospora canker girdling 3-year-old cottonwood.

On trees older than 4 years, cankers usually develop in the crown. Yeast, bacteria, and other microorganisms quickly invade the sap flow from the cankers and cause a fermentation. Foresters refer to the unsightly wounds as "crud cankers." Generally cankers do not girdle the tree, but wind breakage occurs at the wound.

Extreme care should be taken to select only healthy, canker-free cuttings for planting. Proper storage and handling of cuttings will minimize losses. Cuttings should not be allowed to dry out and should be stored at 34 to 40° F until time of planting. Cultivation of 1-year-old plants reduces competition for moisture and nutrition by weeds and thus reduces losses from cankers. Preliminary results show that improved clones may have resistance to *Septoria*, the pioneer organism in the canker complex.



Fusarium canker on 4-year-old cottonwood.



Septoria leaf spots.

SEPTORIA LEAF SPOT

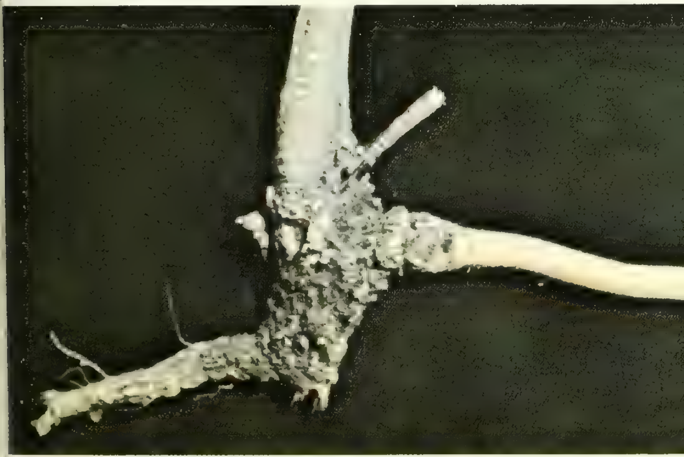
Septoria musiva Peck causes leaf spots as well as the cankers described earlier. The disease is common throughout the United States, parts of Canada, and Argentina. It is a serious threat to nurseries because it provides entry for other disease organisms. In plantations it reduces growth by causing premature defoliation.

Septoria musiva overwinters in fruiting bodies in fallen leaves or branches. In spring, during periods of high humidity, spores are shot into the air. They infect new leaves at bud break. Leaf spots develop 1 to 2 weeks later. Spots first appear as depressed black flecks. Under favorable moisture conditions, flecks increase in size. Spots merge on leaves with multiple infections, and as much as 50 percent of the leaf tissue can be affected. As the dead tissue dries, it fades to light tan or white in the center. Three or 4 weeks after initial infection, spore-producing pycnidia appear as small, black, inconspicuous flecks in the centers of leaf spots. Spores from these pycnidia spread the infection to other cottonwoods.

Control measures would be economically justified in nurseries but probably not in plantations. After cottonwood cuttings are harvested from nursery beds, all debris should be removed or plowed under to destroy infected plant parts and to prevent new shoots from being infected in the spring. Native poplars in or near nurseries should be removed to prevent infection by airborne spores.

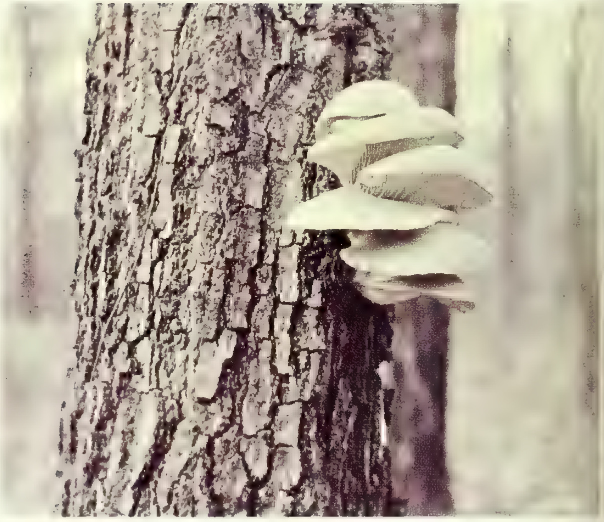
OYSTER MUSHROOM ROT

Pleurotus ostreatus (Fr.) Quel., the oyster mushroom, decays both sapwood and heartwood of several broadleaf tree species throughout the world. Because of its wide occurrence and its ability to attack both root and stem of cottonwood, it is potentially dangerous to cottonwood plantations.



White fungus mycelium of Pleurotus ostreatus **on decayed roots.**

Presence of sporophores (fruiting bodies) on trunks indicate infection. These are 2 to 6 inches (5 to 15 cm) broad, fleshy, smooth, shiny or satiny when dry, and white to grey in color. The cap is convex, with or without an off-center stalk, and has gills on the lower surface where spores are produced. Spores are carried by wind to other areas where they germinate readily under favorable conditions. The fungus enters trees through wounds in stems or roots. A white, flaky rot results. Trees with infected root systems show top symptoms characteristic of root disorders, i.e., a growth decline, unthrifty condition, and a thin crown. Diseased trees do not compete well with adjacent trees, become suppressed, and die within a few years.

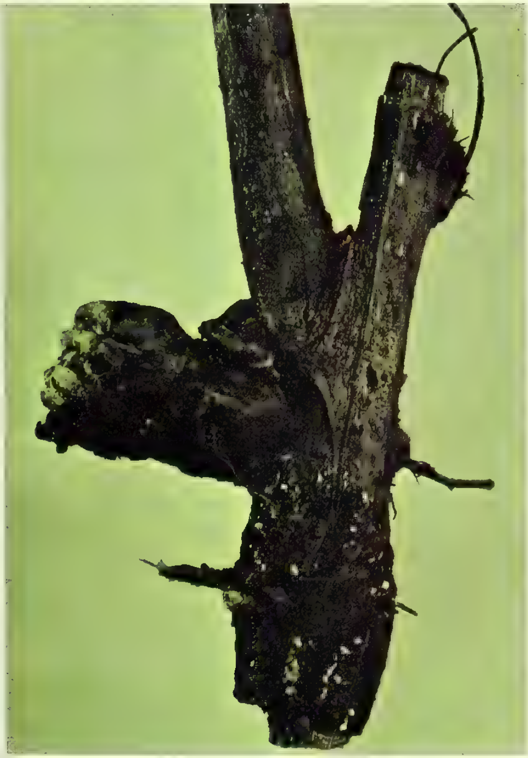


Pleurotus ostreatus **fruiting body.**

This disease can be reduced by avoiding wounds to the root system and basal stem of trees. Removal of infected trees and wood debris harboring the fungus would also help reduce its spread.

LUCIDUS ROOT AND BUTT ROT

Polyporus lucidus Leys. ex Fr. causes rot in roots and the basal stem of hardwood trees in the United States, Europe, the Phillippines, other parts of Asia, and North Africa. The fungus has been observed on cottonwood cuttings but not on established trees. However, since inoculum will be present in many sites intended for cottonwood, infection of established cottonwoods is anticipated.

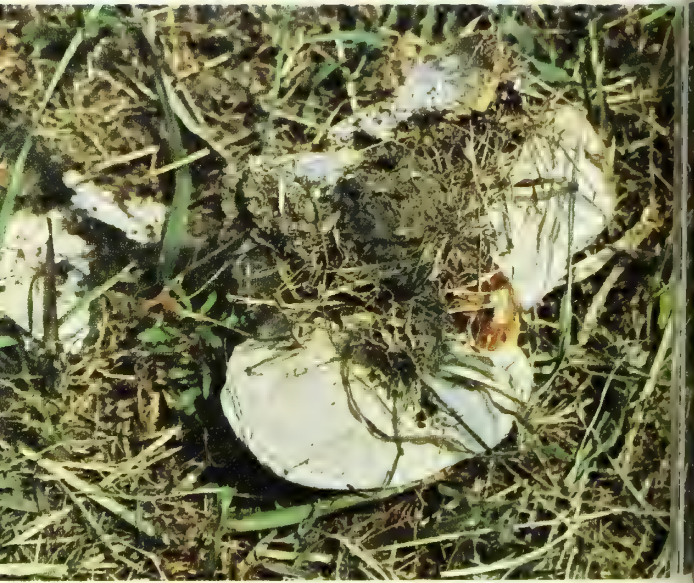


Polyporus lucidus **fruiting body on decayed cutting.**

If attacked, cottonwood would probably develop moderate to slight disease symptoms such as thin crowns and stunted foliage. Later, sporophores will be produced on or near the base of infected trees in late summer or fall.

These mushroom-shaped sporophores are a glossy reddish brown with a white, round margin. The undersurface is whitish with numerous small pores. The stalk is also glossy, dark red. Sporophores vary from 1 to 6 inches (2.5 to 15 cm) high and from 1 to 10 inches (2.5 to 25 cm) in diameter. Brown microscopic spores are released from the fine tubes in the undersurface of the sporophore cap. These spores are carried by wind and germinate on wood debris, stumps, or open wounds on living trees. As the fungus grows, it can penetrate the root system or collar of nearby susceptible trees. The wood decay is a soft, spongy, white rot with black spots.

No practical control is known for this disease. However, avoiding mechanical injuries to roots and tree bases, avoiding sites with known infections of natural stands, or removing infected trees helps reduce infections.

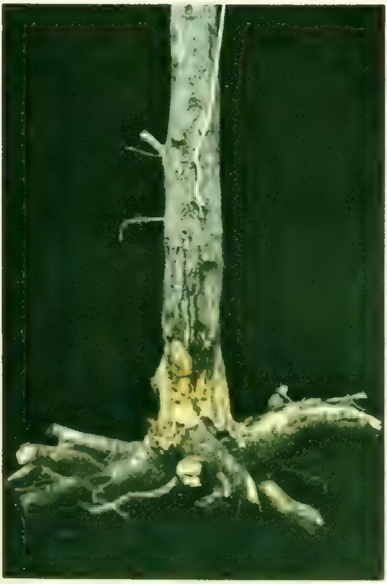


Typical P. lucidus **fruiting bodies growing above diseased roots.**

CLITOCYBE ROOT ROT

Root rot caused by *Clitocybe tabescens* Bres. ccurs on many woody plants in the Southeastern tates and elsewhere throughout the world. The isease has been observed in cottonwood plantaions, but its full impact on this species has not et been assessed.

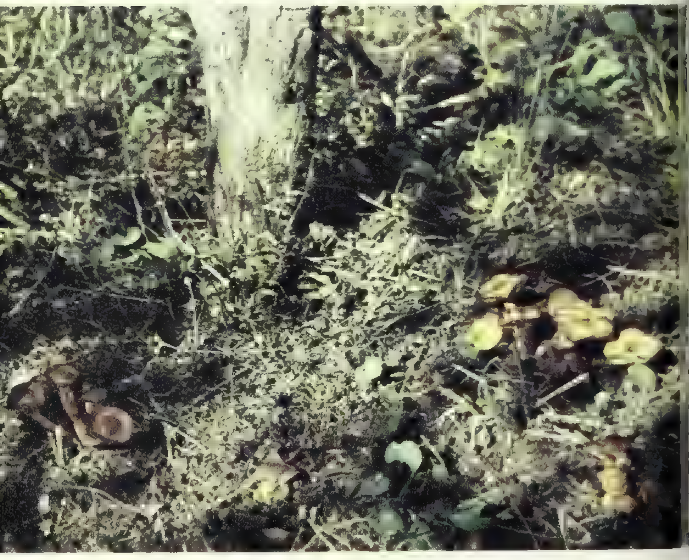
First noticeable symptoms may be a decline of he crown and yellowing leaves, which fall prematurely or remain small and scant. On small trees, ll foliage may die. White, fan-shaped mycelial ungus mats may form on the roots and root collar, ausing decay. These mats extend upward between ark and wood and cause rot in both heartwood nd sapwood.



Root system decayed by Clitocybe tabescens.

In fall dense clusters of yellow-brown mushrooms develop at the base on the infected tree. These mushrooms are 4 to 6 inches (10 to 15 cm) high and have a broad, brown, scaly cap ½ to 2/3 inch (12 to 17 mm) in diameter and whitish gills. They produce wind-borne spores that germinate on exposed tissue of living or dead trees. The fungu spreads through the roots of infected trees an penetrates living roots of adjacent, healthy tree through root grafts or wounds.

Suppressed or off-site trees are apparently mos subject to attack. Thus, the best control is t maintain a vigorous stand through site selection spacing, and thinning. Site preparation should include removal of all roots that might harbor th fungus. Removal of infected trees may be of valu in young stands; however, care must be taken t avoid spreading fungus inoculum.



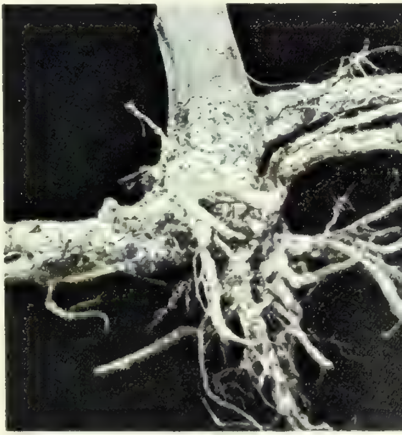
C. tabescens **fruiting bodies above diseased roots.**

CORTICIUM ROOT ROT

White root rot, or Corticium root rot, caused by *Corticium galactinum* (Fr.) Burt. attacks numerous woody and herbaceous perennial species in the United States, Europe, the West Indies, and Japan. Only a few cases of this disease have as yet been observed on cottonwood in plantations, but it is potentially destructive because of its wide occurrence and ability to spread from tree to tree.

Infected trees may only appear unthrifty with thin crowns. However, foliage may turn brown suddenly and die, accompanied by death of twigs and main stem. The sporophore appears on the root surface as a white or cream-colored layer of fungal growth without definite form or features and may persist for some time. The exposed sporophore surface may appear dry and cracked. Spores are wind disseminated. Under favorable conditions, they germinate and invade dead woody tissues or may even invade living root tissues. The fungus then spreads through the tissues, killing living cells and decaying the wood. Wood of affected roots often shows concentric spots, and roots may appear knotted or gnarled. Diseased trees occur singly or in small randomly located groups.

There are no practical control measures for this disease. However, avoiding sites where native stands are known to be infected and removing diseased trees from plantations are beneficial measures. Care should be taken so that pieces of infected roots or other inoculum are not spread to other areas. Replacement of plantation trees killed by this disease is generally not effective.



Corticium galactinum **fruiting bodies on decayed roots.**

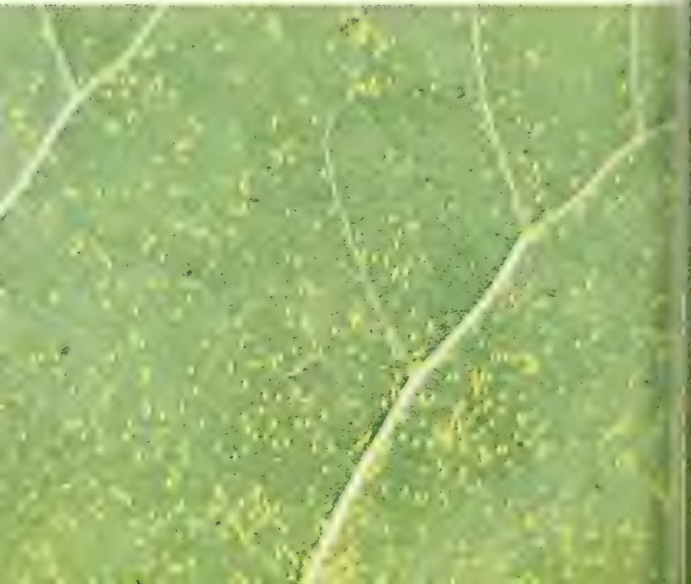
MELAMPSORA LEAF RUST

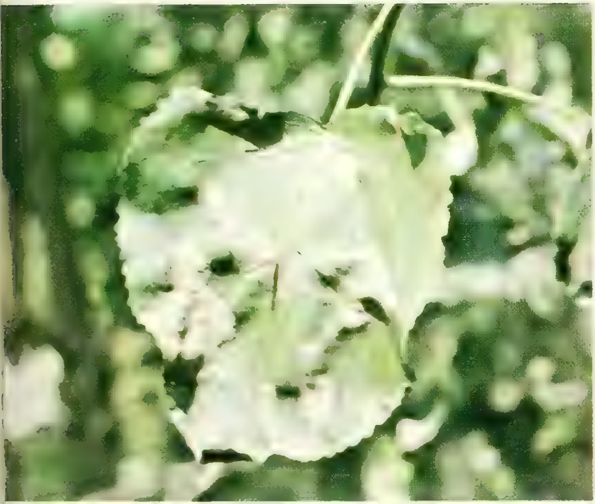
Leaf rust caused by *Melampsora medusae* Thum causes economic losses in nursery stock throughou the geographic range of cottonwood. Above latitude 40°, rust may cause premature defoliation in plantations. This defoliation not only causes growth losses; it weakens the trees and predisposes them to other pathogens, which cause cankers and mortality.

Cottonwood leaves are infected in early spring by wind-borne spores produced on conifers or by spores that overwintered on cottonwoods in frost-free areas. The first evidence of the disease is small yellow spots (masses of spores) on the lower leaf surfaces. These rust spores can be blown to new leaves and cause additional infections. I humidity is high, infection may spread until the entire leaf is covered by yellow spores. Defoliation usually occurs when rust covers over 50 percent o the leaf. Late in the season, the disease is easily detectable by the vast amount of rust spores, which give the leaves a dusty yellow color.

Rust-resistant clones developed by the Southern Forest Experiment Station in Stoneville, Mississippi, are available through several State fores nurseries. Stoneville clones 75 and 92 are not defoliated by rust and should be favored in areas when summer defoliation occurs.

Melampsora rust spores.





Alternaria leaf blight.

ALTERNARIA LEAF AND STEM BLIGHT

Leaf and stem blight caused by *Alternaria tenuis* ees occurs in the United States, Canada, and Mex-o. It was first reported on cottonwood in North akota in 1918. It now appears to be an important isease in nurseries and plantations. Losses among nrooted, green-tip cuttings in mist beds can be high as 65 to 95 percent.

The fungus overwinters as mycelia on plant ebris. In spring wind-borne spores are carried new leaves; they germinate within 1 to 2 hours hen relative humidity is 100 percent and temprature is between 40 and 95° F. The spore can enetrate epidermal tissue of young leaves and ems, but it usually enters through leaf margins nd insect wounds, turning tissue brown. Within to 7 days, mycelia have formed, and new spores re being produced. The infested area now appears a sooty, irregularly shaped blotch.

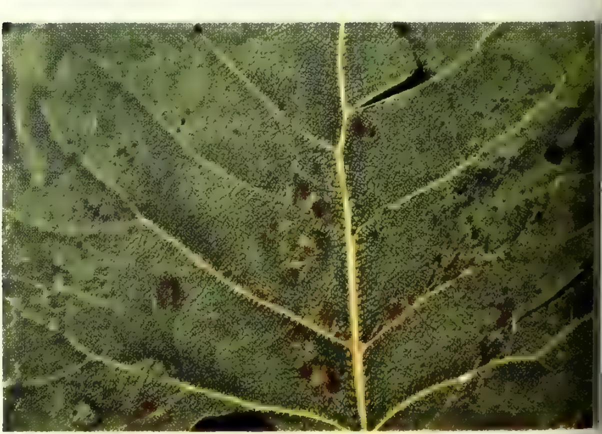
Rotation and sanitation of nursery planting beds ill reduce incidence of this disease by eliminating ngus which overwinters on plant debris. Early pring cultivation of stool beds to turn-under plant ebris will greatly reduce subsequent infections.

MINOR LEAF DISEASES

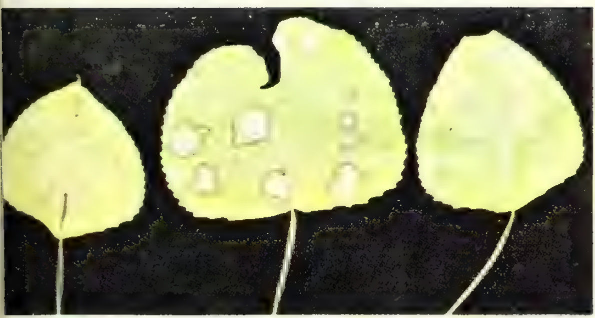
Several fungi cause leaf diseases on cottonwood throughout its geographic range. Leaf spot diseases may become epidemic during a wet spring and summer. Although the unsightly leaves and excessive leaf fall can be spectacular, they usually cause only minimal growth loss. A leaf disease is a serious problem only when more than half the leaf surface is infected or defoliation removes more than half the leaves. Heavy infections for several successive years can predispose the tree to other pathogens, which could cause death.

The most common fungi which cause damage are *Taphrina populina* Fr., *Phyllosticta* sp., *Cercospora populina* E. & E., *Colletotrichum gloeosporioides* Penz. These fungi overwinter on fallen leaves or twigs. In early spring spores are produced which infect leaves, causing death of leaf tissue. The affected area may be as small as a pinpoint or up to several inches in diameter. It can appear as a spot, ring, blotch, anthracnose, leaf curl, or leaf blister. Often more than one leaf disease is present on a single leaf.

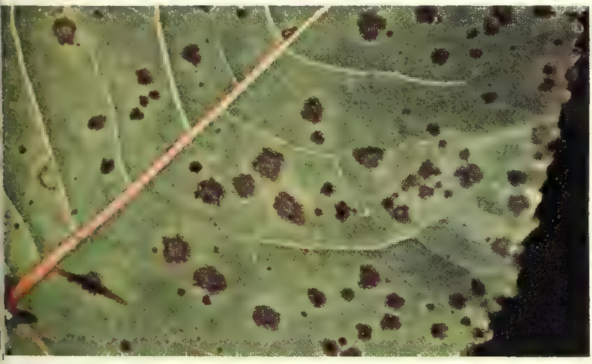
Sanitation reduces the possibility of epidemics by reducing the amount of inoculum. In most cases the disease is sporadic, and epidemics do not occur annually. If heavy defoliation occurs in successive years, chemical control may be needed to reduce subsequent infections.



Leaf blister caused by Taphrina populina.

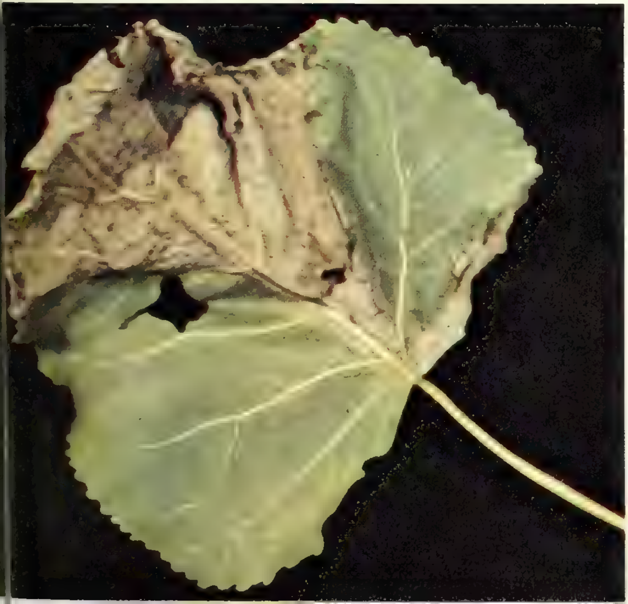


Phyllosticta ring spot.



Leaf spot caused by Cercospora populina.

Anthracnose caused by Colletotrichum gloeosporioides.



EPA registered chem
wood. (See labels fo

Insect
Cottonwood leaf beet
Cottonwood twig bor
Cottonwood clearwir borers
Borers
Leaf curl mites
Leafhoppers
Aphids Leafminers Leaf rollers

Disease
Leaf spots & blotches
Anthracnose

Pesticides used improperl
the directions and heed a

Store pesticides in origi
of children and animals—

Apply pesticides so that t
insects, fish, and wildlife.
when honey bees or oth
that may contaminate wa

Avoid prolonged inhalati
and equipment if specifi

If your hands become co
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If a pesticide is spilled o
and wash skin thoroughl

Do not clean spray eq
streams, or wells. Becaus
equipment, do not use t
you use for herbicides.

Dispose of empty pesticid
land-fill dump, or crush

NOTE: Some States hav
your State and local reg
under constant review b
county agricultural agen
use is still registered.

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[1] Effective as of May
of this table will b
701 Loyola Ave., N

[2] Registration is not

[3] Mention of trade r
endorsement by the

EPA registered chemicals [1] for control of insects and diseases that attack cottonwood. (See labels for dosages and application methods.)

Insect	Insecticide	Host registered on [2]
Cottonwood leaf beetle	Carbofuran (Furadan^{R})	Nursery plants, trees Cottonwood plantations
Cottonwood twig borer	Carbofuran (Furadan^{R})	Nursery plants, trees Cottonwood plantations
Cottonwood clearwing borers	Carbofuran (Furadan^{R})	Nursery plants, trees Cottonwood plantations
Borers	Lindane	Poplar & willow trees
Leaf curl mites	Carbaryl (Sevimol-4^{R})	Ornamental trees
Leafhoppers	Azinophos-Methyl (Guthion^{R})	Nursery plants, trees
	Carbaryl (Sevin^{R})	Ornamental trees
	Chlorpyrifos (Dursban^{R})	Ornamental trees
	Diazinon	Ornamental trees
	Malathion	Ornamental trees
	Oxydematon-Methyl (Meta-Systox-R^{R})	Nursery trees
Aphids	Azinophos-Methyl (Guthion^{R})	Nursery plants, trees
Leafminers	Naled (Dibrom^{R})	Broadleaf trees
Leaf rollers	Carbaryl (Sevin^{R})	Ornamental trees
Disease	**Fungicide**	**Host registered on**
Leaf spots & blotches	Benomyl (Benlate^{R}) Lime sulphur	Ornamentals Deciduous trees
Anthracnose	Benomyl (Benlate^{R}) Lime sulphur	Ornamentals Deciduous trees

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[1] Effective as of May 1975. As new controls are tested and registered, revisions of this table will be available from the Southern Forest Experiment Station, 701 Loyola Ave., New Orleans, La. 70113.

[2] Registration is not limited to cottonwood unless so stated.

[3] Mention of trade names is solely to identify materials and does not imply endorsement by the U. S. Department of Agriculture.

CAUTION

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U. S. Department of Agriculture, consult your county agricultural agent or State Extension specialist to be sure the intended use is still registered.

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Combining-Ability Determinations for Incomplete Mating Designs

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COMBINING-ABILITY DETERMINATIONS FOR INCOMPLETE MATING DESIGNS

E. B. Snyder[1]

It is shown how general combining ability values (GCA's) from cross-, open-, and self-pollinated progeny can be derived in a single analysis. Breeding values are employed to facilitate explaining genetic models of the expected family means and the derivation of the GCA's. A FORTRAN computer program also includes computation of specific combining ability values and several options.

Additional keywords: Diallel cross, reciprocal cross, specific combining ability, *panmixia.*

The plant breeder ranks parents according to their eneral combining abilities. The calculation of mean ffects is complicated when all parents of a particuar set have not been crossed systematically, but heories and procedures for analyzing even severely nbalanced data are nevertheless available (Bohren t al. 1965, Gilbert 1967).

The mathematics of such theories may present ifficulties to the practical breeder. Here, I advance simplified explanation by showing how breeding alues ($2\ \mathrm{GCA} + \overline{\mathrm{X}}$ terms) can be manipulated for nalyzing data from cross, self, and open pollinaons in a single analysis. I will also discuss the useılness of selfing, a means of testing the randomness f open-pollination, a technique for estimating the opulation mean, and a method for combining data om several experiments.

As computer programs for such unbalanced data ave generally not been published, a versatile, effient FORTRAN program is described along with bstitute procedures requiring no more than a desk lculator.

THEORY AND APPLICATIONS

When reciprocal crosses are pooled, a model for determining general combining ability effects (GCA's) from intercrossed parents is:

$$y_{ijk}=\mu+\mathrm{gca}_i+\mathrm{gca}_j+\varepsilon_{ijk}$$

where y_{ijk} = k^{th} individual in the i, j^{th} cross
gca_i = GCA effect of the i^{th} parent
gca_j = GCA effect of the j^{th} parent

with the assumptions that

$$\Sigma n_i \mathrm{gca}_i=0$$

$$\{\varepsilon_{ijk}\}\sim\mathrm{NID}\ (0,\sigma^2)$$

where n_i = the number of plants per family (given a value of 1 in unweighted analyses).

The GCA estimates are applicable only to the restricted set of parents tested, i.e., the model is fixed.

Breeding values ($2\ \mathrm{GCA}+\overline{\mathrm{X}}$) are easily visualized and hence facilitate explaining the genetic model. A value of the i^{th} parent is ($2\ \mathrm{GCA}_i+\overline{\mathrm{X}}$), or twice the parental contribution to an individual progeny. The models for the expected family means (mid-parental values) of individual progeny of various types are:

Cross-pollinated $$\frac{(2\ \mathrm{GCA}_i+\overline{\mathrm{X}})+(2\ \mathrm{GCA}_j+\overline{\mathrm{X}})}{2}$$

$$=\mathrm{GCA}_i+\mathrm{GCA}_j+\overline{\mathrm{X}}$$

Self-pollinated $$\frac{(2\ \mathrm{GCA}_i+\overline{\mathrm{X}})+(2\ \mathrm{GCA}_i+\overline{\mathrm{X}})}{2}$$

$$=2\ \mathrm{GCA}_i+\overline{\mathrm{X}}$$

Open-pollinated $$\frac{(2\ \mathrm{GCA}_i+\overline{\mathrm{X}})+(2\ \mathrm{GCA}_{op}+\overline{\mathrm{X}})}{2}$$

$$=(\mathrm{GCA}_i+\mathrm{GCA}_{op}+\overline{\mathrm{X}}$$

or ($\mathrm{GCA}_i+\overline{\mathrm{X}}$), because $\mathrm{GCA}_{op}=0$.

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Since formulae for all three family types are built up from breeding values, observed means can be used to calculate breeding values for each family type. Furthermore, breeding values for each type can be entered independently or together in a single diallel analysis, thereby giving more replication and confidence to estimates.

Selfs should be incorporated only if there is no inbreeding depression. As the structural model shows, an extreme breeding value is doubled among selfed progeny, whereas among crosses it is diluted by being paired with a less extreme value. Thus, the extremeness is a "selfing" effect only in the sense that a single extreme breeding value (variant) would not be so conspicuous in cross-pollinated progeny. If there were no inbreeding effect or if it could be compensated for, selfing would efficiently and unambiguously identify extreme parents.

Provided there are some parents in common, populations of various types of material from different experiments can be used in a single diallel table by adjusting breeding values and, from these, the phenotypes to be integrated. Combining populations thus requires the preliminary analysis of each and subsequently calculating the adjusting ratios from the average of breeding values in common. Similarly, data from separate plantings of the same families may be combined after appropriate adjustments.

Data from open-pollinated (OP) families can be included in the same analysis with those from cross-pollinated families. This is possible when wind-borne pollen is treated as that from a single male parent representing the population. Two values of interest to the breeder can be deduced from the OP model. Deviation of the GCA_{op} value from zero measures the deviation of selected females from randomness. Also, the mean of the population is estimated by the OP breeding value.

The computer calculations are based on the usual least-squares methods suggested by Gilbert (1967) and illustrated by England (1974). If a computer is not available, iteration with a calculating machine will serve. Thus, for unweighted analysis with reciprocals absent or pooled and no selfs (Yates 1947), parental mean of ith parent, $\overline{P}_i \cong$

$$\frac{\text{Breeding value of } i^{th} \text{ parent } + \overline{BV} \text{ of other parents crossed with } P_i}{2}$$

For example, the breeding value for parent 3 of a 13-parent half-diallel with no selfs becomes:

$$(2\ GCA_3+\overline{X})=2\overline{P}_3-1/12(2GCA_1+\overline{X}+2\ GCA_2+$$
$$\overline{X}+2GCA_4+\overline{X}\ldots+2GCA_{13}+\overline{X})$$

The $\overline{P}_3$ value is the mean of all families for which P is a parent. When the initial equations are set up, $\overline{P}$ values must be substituted for the $(2GCA_i+\overline{X})$ values within the righthand parentheses. As the analysis continues, $(2GCA_i+\overline{X})$ values are entere as soon as determined. Usually, satisfactory convergence will be achieved with five or fewer iterations.

Once the breeding values are found, specifi combining abilities may be computed directly in the usual way:

$$\text{SCA}=\text{observed mean of } i^{th},\ j^{th} \text{ family} - \frac{(2\,GCA_i+\overline{X})+(2GCA_j+\overline{X})}{2}$$

By definition, SCA's are not appropriate for selfs

Because the mid-parental expectation of a cros is the last term in the formula, definition and use o $(2\ GCA+\overline{X})$ breeding values is easy. They ar simply parental values which, when averaged, predict performance of the cross. The convenience an ease of visualization for instruction and breedin are lacking with GCA or 2 GCA deviations alone.

THE PROGRAM

The mathematics of the program is similar to tha used by most statisticians—least-squares equation are formed and GCA values are solved for by inverting the matrix according to the elimination metho For some limitations to the program, Gilbert (1967 should be consulted. Solutions may differ slightl depending on the degrees of design balance an order in which data are fitted. Also, if it is desired t estimate values separately within male or femal sets, Milliken et al. (1970) should be consulted.

The usefulness of the program lies with its supplementary options and listings:

Sum or mean data with or without the numbe of plants per family may be entered for as man as 50 parents. Options are offered for weightin by number of plants, not weighting, or both. If n reciprocal crosses are present, data are entered upper-triangle matrix elements. Reciprocal dat are entered in the lower triangle and will automatically be accumulated or averaged into th upper triangle.

Input or data errors will be signalled, aft which the analysis will be terminated and the ne one started. Warnings of some types of singular near-singular solutions are given. The program is generously supplied with comment cards that should facilitate modification by others.

Listed in addition to combining ability and breeding values are: the data entered, family means, number of parents, effective number of families per parent, mean breeding value, and experimental mean.

The inverse is printed for possible use in obtaining confidence intervals for the GCA values (Milliken et al. 1970). An error mean square must be available from a separate variance-analyzing program. The program of Schaffer and Usanis (1969) is adequate and so versatile that we do not supply variance terms except for a GCA sum of squares for comparison with it and other programs.

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```
C     E.B.SNYDER-W.NANCE.SFES THIS PROGRAM IS FOR ANY TYPE OF DIALLEL
C     BUT ASSUMES NO SELFING EFFECTS.SUMS WITH PLANT COUNTS/FAMILY,AND
C     MEANS WITH OR WITHOUT COUNTS MAY BE ENTERED TO OBTAIN WEIGHTED OR
C     UNWEIGHTED VALUES.ALL TYPES OF DATA ARE ACCUMULATED IN UPPER TRI-
C     ANGLE OF MATRICES FOR ANALYSIS
C
C     **************
C     * CARD ORDER *
C     **************
C
C        CONTROL CARD       **
C        INPUT FORMAT CARD    * REPEATED FOR EACH EXPERIMENT
C        TITLE CARD           *
C        DATA CARDS         **
C
C        TRAILER CARD ** CONSISTS OF A BLANK CARD USED ONLY AFTER FINAL
C                                 DATA SET
C
C     ****************
C     * CONTROL CARD *
C     ****************
C
C       COLS.1-7 CONTROL
C       COLS.8-10 PROBLEM NO.
C       COLS.11-13 NUMBER OF PARENTS
C       COLS.14-17 NO. OF FAMILIES WITH DATA--LEAVE BLANK IF COL.19 IS 0
C
C                        * 1 IF ID IS PROVIDED WITH DATA
C       COLS.18-19 PUNCH*
C                        * 0 IF NO ID IS PROVIDED. IN THIS CASE ZEROS
C                            MUST BE ENTERED WHERE MISSING DATA
C
C                          *1 IF DATA ENTERED ARE SUMS AND PLANTS/FAMILY
C       COL.   21 PUNCH * 2 IF DATA ENTERED ARE MEANS AND PLANTS/FAMILY
C                          *3 IF DATA ENTERED ARE MEANS ONLY
C
C                          *1 IF ANALYSIS WEIGHTED BY PLANTS/FAMILY
C       COL.   23 PUNCH * 2 IF WEIGHTED AND UNWEIGHTED ANALYSIS
C                          *3 IF UNWEIGHTED ANALYSIS
C
C     *********************
C     * INPUT FORMAT CARD *
C     *********************
C
C        PLANTS/FAMILY,IF USED,ARE ENTERED IN F FORMAT
C
C     **************
C     * TITLE CARD *
C     **************
C
C       COLS.1-5 TITLE
C       COLS.8-72 TEXTUAL IDENTIFICATION OF THE VARIABLE OR CHARACTER
C
C     **************
C     * DATA CARDS *
C     **************
C
C       ONE TRAIT AT A TIME IS ANALYZED. MEASUREMENT DATUM FOR A FAMILY
C       IS PREFERABLY PRECEDED BY PARENTAL COMPOSITION ID,WHERE FEMALE
C       (CODED SEQUENTIALLY 1 TO N) IS IMMEDIATELY FOLLOWED BY A SIMIL-
C       ARLY CODED MALE,E.G.0102 GIVES BOTH PARENTAGE AND MATRIX INDI-
C       CES. THE MEASUREMENT DATA MAY BE FOLLOWED IN THE SAME FIELD BY
C       NUMBER OF PLANTS/FAMILY. SEE OPTIONS LISTED FOR CONTROL CARDS
C       ABOVE.THE DATA FROM MORE THAN ONE PLANT CAN BE PLACED ON ONE
```

```
C         CARD ONLY IF ID'S ARE NOT SUPPLIED BUT HERE THERE ARE NO INPUT
C         ERROR CHECKS. ALL DATA ARE ENTERED BY ROWS AND, IF THERE ARE NO
C         RECIPROCAL CROSSES,IN THE UPPER TRIANGLE. WHERE THE TRUE VALUE
C         OF DATUM IS ZERO, A VERY SMALL NUMBER MUST BE ENTERED INSTEAD.
C
C***********************************************************************
C
C
      REAL NN,MM,KK
      INTEGER P1,DE,WT,W,EMPTY,CONTRO
      DIMENSION U(50,50), X(50,50), IX(50,50), KK(50,50), MM(50,50), NN(
     150,50), Q(50,50), Y(50,1), N(50), P(50), B(50), G(50), FMT(12), TI
     2TLE(11), XPY(50,1)
C     FOR SOME COMPUTERS THE FOLLOWING MAY BE NEEDED
C     DIMENSION RAY(50,50), BB(50,1), JJ(50)
      EQUIVALENCE (IX,X)
      DATA CONTRO /6HCONTRO/
      DATA IOU,IIU /6,5/
      DATA EMPTY /5HEMPTY/
      WRITE (IOU,530)
    5 READ (IIU,570,END=520) IA
      IF (IA.NE.CONTRO) GO TO 60
   10 READ (0,540) P1,NF,ID,DE,WT
   20 IF (P1.EQ.0) GO TO 520
      READ (IIU,550) (FMT(I1),I1=1,12)
      READ (IIU,590) (TITLE(I3),I3=1,11)
      DO 30 IJK=1,P1
        DO 30 IKL=1,P1
          NN(IJK,IKL)=0.
          IX(IJK,IKL)=EMPTY
   30     CONTINUE
      IF (ID.EQ.1) GO TO 40
      IF (ID.EQ.0.AND.DE.LT.3) READ (IIU,FMT) ((X(I,J),NN(I,J),J=1,P1),I
     1=1,P1)
      IF (ID.EQ.0.AND.DE.EQ.3) READ (IIU,FMT) ((X(I,J),J=1,P1),I=1,P1)
      GO TO 80
   40 DO 50 IJK=1,NF
        IF (DE.LT.3) READ (IIU,FMT) IFEM,IMAL,XIN,XNNIN
        IF (DE.EQ.3) READ (IIU,FMT) IFEM,IMAL,XIN
        IF (IFEM.LE.0.OR.IFEM.GT.P1) GO TO 60
        IF (IMAL.LE.0.OR.IMAL.GT.P1) GO TO 60
        IF (IX(IFEM,IMAL).NE.EMPTY) GO TO 60
        X(IFEM,IMAL)=XIN
        IF (DE.LT.3) NN(IFEM,IMAL)=XNNIN
   50   CONTINUE
      GO TO 80
   60 WRITE (IOU,560)
C     SEARCH FOR OTHER PROBLEMS SUBMITTED BUT AN ERROR CAN RUIN THE
C     READING IN OF IMMEDIATELY FOLLOWING PROBLEM(S)
   70 READ (IIU,570,END=520) IA
      IF (IA.NE.CONTRO) GO TO 70
      READ (0,540) P1,NF,ID,DE,WT
      GO TO 20
   80 WRITE (IOU,580)
      WRITE (IOU,590) (TITLE(I3),I3=1,11)
      WRITE (IOU,600) P1
      DO 90 I1=1,P1
        DO 90 I2=1,P1
          IF (IX(I1,I2).EQ.EMPTY) X(I1,I2)=0.
   90     CONTINUE
      KOUNT=0
      DO 100 I=1,P1
        DO 100 J=1,P1
          U(I,J)=X(I,J)
  100     CONTINUE
```

```
      IF (DE.NE.1) GO TO 120
      DO 110 I=1,P1
        DO 110 J=1,P1
          IF (NN(I,J).EQ.0.) GO TO 110
          X(I,J)=X(I,J)/NN(I,J)
  110     CONTINUE
C     TEST FOR RECIPROCALS IN LOWER TRIANGLE
  120 DO 130 I=2,P1
        L=I-1
        DO 130 J=1,L
  130     IF (X(I,J).GT.0.) GO TO 420
      W=0.
C     GIVES NATURE OF DATA ENTERED AND WEIGHTING DESIRED
  140 IF (DE.NE.1) GO TO 150
      WRITE (IOU,610)
  150 IF (DE.NE.3) GO TO 190
      WRITE (IOU,620)
      IF (DE.EQ.3.AND.WT.EQ.3) GO TO 160
      WRITE (IOU,630)
  160 WRITE (IOU,640)
C     ENTER 1´S IN NN MATRIX IF UNWEIGHTED ANALYSIS
      DO 170 IJK=1,P1
        DO 170 IKL=1,P1
  170     NN(IJK,IKL)=0.
      DO 180 I=1,P1
        DO 180 J=1,P1
          IF (X(I,J).NE.0.) NN(I,J)=1.
  180     CONTINUE
      GO TO 210
  190 IF (DE.EQ.1) GO TO 200
      WRITE (IOU,650)
  200 IF (WT.EQ.3) GO TO 160
      WRITE (IOU,660)
  210 DO 220 I=1,P1
        DO 220 J=I,P1
  220     KK(I,J)=NN(I,J)
C     ADJUST FREQ OF SELFS IN DIAG OF NN
      DO 230 I=1,P1
        NN(I,I)=4.*NN(I,I)
  230   CONTINUE
      KOUNT=KOUNT+1
      DO 240 I=1,P1
        N(I)=0
        P(I)=0.
  240   B(I)=0.
      N2=0
C     START MAIN PROGRAM BY SETTING SELF DATA IN ACCUMULATORS
      DO 250 I=1,P1
        N(I)=0.5*NN(I,I)
        P(I)=0.5*NN(I,I)*X(I,I)
  250   CONTINUE
C     ACCUMULATE YIELDS AND COUNTS FOR EACH PARENT
      DO 260 J=2,P1
        L=J-1
        DO 260 I=1,L
          IF (X(I,J).EQ.0.) GO TO 260
          N(I)=N(I)+1
          N(J)=N(J)+1
          P(I)=P(I)+NN(I,J)*X(I,J)
          P(J)=P(J)+NN(I,J)*X(I,J)
  260     CONTINUE
      DO 270 I=1,P1
        N2=N2+N(I)
  270   CONTINUE
C     ARRANGE P(J) IN MATRIX AND PRINT
```

```
      DO 280 J=1,P1
        Y(J,1)=2.*P(J)
  280   CONTINUE
      DO 290 I=1,P1
        XPY(I,1)=Y(I,1)
  290   CONTINUE
C     DUPLICATE UPPER NN ELEMENTS IN LOWER TRIANGLE
      DO 300 I=1,L
        DO 300 J=2,P1
  300     NN(J,I)=NN(I,J)
C     ACCUMULATE TOTAL ADJUSTED COUNTS IN DIAGONALS
      DO 320 J=1,P1
        N(J)=0.
        DO 310 I=1,P1
          N(J)=N(J)+NN(J,I)
  310     CONTINUE
        NN(J,J)=N(J)
  320   CONTINUE
      WRITE (IOU,670)
      WRITE (IOU,680) (NN(I,I),I=1,P1)
      CALL MATINV (NN,P1,Y,1,DETERM,NDEP,1)
      WRITE (IOU,690) NDEP
      S=0.
      DO 330 I=1,P1
        B(I)=Y(I,1)
        S=S+B(I)
  330   CONTINUE
      XP1=P1-NDEP
      S=S/XP1
      IF (NDEP.EQ.0) GO TO 335
      S=S/2.0
      JXP1 = XP1
      DO 332 I = 1,JXP1
      B(I)=B(I)-S
  332   CONTINUE
  335 WRITE (IOU,700) S
C     MEAN AND SS TERMS LINK WITH ANV
      SUM1=0.
      SUM2=0.
      SUM3=0.
      DO 340 I=1,P1
        DO 340 J=1,P1
          SUM1=SUM1+X(I,J)*KK(I,J)
          SUM2=SUM2+KK(I,J)
  340     CONTINUE
      DO 350 I=1,P1
        SUM3=SUM3+XPY(I,1)*Y(I,1)
  350   CONTINUE
        X1=SUM1/SUM2
      SUM2=((SUM1)**2)*SUM2
      SUM3=(SUM3/4.0)-SUM2
      WRITE (IOU,710)
      WRITE (IOU,720) SUM2
      WRITE (IOU,730) SUM3
      WRITE (IOU,740) SUM1
      DO 360 J=1,P1
      IF (B(J).EQ.0.) B(J)=S
        G(J)=((B(J)-S)/2.0)
  360   CONTINUE
      DO 370 I=1,P1
        L=I+1
        DO 370 J=L,P1
          IF (X(I,J).EQ.0.) Q(I,J)=0.
          IF (X(I,J).NE.0.) G(I,J)=X(I,J)-(B(I)+B(J))/2.0
  370     CONTINUE
```

```
      WRITE (IOU,750)
      CALL MPRINT (NN,P1,1,6HNN MAT)
      IF (DE.GT.1.AND.W.EQ.0) GO TO 390
      IF (DE.EQ.1.AND.W.EQ.0) GO TO 380
      WRITE (IOU,760)
      CALL MPRINT (MM,P1,1,6HMM MAT)
      WRITE (IOU,770)
      CALL MPRINT (U,P1,1,6H U MAT)
      GO TO 390
  380 WRITE (IOU,780)
      CALL MPRINT (U,P1,1,6H U MAT)
  390 WRITE (IOU,790)
      WRITE (IOU,800) (G(I),I=1,P1)
      WRITE (IOU,810)
      WRITE (IOU,820) (B(I),I=1,P1)
      WRITE (IOU,830)
      LINES=0
      DO 410 I=1,P1
        DO 410 J=I,P1
          IF (KK(I,J).EQ.0.) GO TO 410
          LINES=LINES+1
          IF (LINES.NE.51) GO TO 400
          LINES=0
          WRITE (IOU,830)
  400     WRITE (IOU,840) I,J,KK(I,J),X(I,J),Q(I,J)
  410     CONTINUE
      IF (WT.EQ.2.AND.KOUNT.LT.2) GO TO 160
      GO TO 5
C     THIS ENDS ANALYSIS
  420 W=1.
C     THE FOLLOWING PUTS RECIPS IN HALF DIALLEL FORM
      IF (DE.LT.3) GO TO 450
      DO 430 IJK=1,P1
        DO 430 IKL=1,P1
  430     NN(IJK,IKL)=0
      DO 440 I=1,P1
        DO 440 J=1,P1
  440     IF (X(I,J).NE.0.) NN(I,J)=1.
  450 DO 460 I=1,P1
        DO 460 J=1,P1
          X(I,J)=NN(I,J)*X(I,J)
  460     CONTINUE
      DO 470 I=1,P1
        DO 470 J=1,P1
  470     MM(I,J)=NN(I,J)
      DO 480 I=1,P1
        DO 480 J=1,P1
          NN(I,J)=NN(I,J)+NN(J,I)
          X(I,J)=X(I,J)+X(J,I)
  480     CONTINUE
      DO 490 I=1,P1
        NN(I,I)=0.5*NN(I,I)
        X(I,I)=0.5*X(I,I)
  490   CONTINUE
      DO 500 I=2,P1
        L=I-1
        DO 500 J=1,L
          NN(I,J)=0.
          X(I,J)=0.
  500     CONTINUE
      DO 510 I=1,P1
        DO 510 J=I,P1
          IF (X(I,J).EQ.0.) GO TO 510
          X(I,J)=X(I,J)/NN(I,J)
```

```
*        510      CONTINUE
*           GO TO 140
*        520 STOP
*     C
*        530 FORMAT (1H1,61H        GCA AND SCA VALUES FOR COMPLETE OR INCOMPLET
*           1E DIALLELS)
*        540 FORMAT (10X,I3,I4,3I2)
*        550 FORMAT (12A6)
*        560 FORMAT (1H0,65H END OF ANALYSIS OR TERMINATION DUE TO INPUT FORMAT
*           1 OR DATA ERROR)
*        570 FORMAT (A6)
*        580 FORMAT (1H0,51H * * * * * * * * * * * * * * * * * * * * * * * * *
*           1)
*        590 FORMAT (1H0,6X,11A6)
*        600 FORMAT (1H0,25H THE NUMBER OF PARENTS IS,I4)
*        610 FORMAT(1H0,41H DATA ENTERED WERE SUMS AND PLANTS/FAMILY)
*        620 FORMAT (1H0,29H DATA ENTERED WERE MEANS ONLY)
*        630 FORMAT (1H0,31H WEIGHTED ANALYSIS NOT POSSIBLE)
*        640 FORMAT (1H0,20H UNWEIGHTED ANALYSIS)
*        650 FORMAT (1H0,46H DATA ENTERED WERE MEANS AND PLANTS PER FAMILY)
*        660 FORMAT (1H0,18H WEIGHTED ANALYSIS)
*        670 FORMAT (1H0,82H THE EFFECTIVE NUMBER OF FAMILIES OR PLANTS PER PAR
*           1ENT(RECIPS ABSENT OR POOLED)ARE)
*        680 FORMAT (1H ,10F10.1)
*        690 FORMAT (1H0,107H WHENEVER A DEPENDENCY(SINGULAR MATRIX) OCCURS THE
*           1 GCA EFFECT IS SET TO ZERO. THE NUMBER OF DEPENDENCIES IS ,I3)
*        700 FORMAT (1H0,28H THE MEAN(2GCA+XBAR)VALUE IS,E16.9)
*        710 FORMAT (1H0,117H IF CORRECT DATA WERE ENTERED THE FOLLOWING WILL C
*           1ORRESPOND TO TERMS FOUND BY INDEPENDENTLY DERIVED LEAST SQUARES AN
*           2V)
*        720 FORMAT (1H0,23H THE CORRECTION TERM IS,E16.9)
*        730 FORMAT (1H0,31H THE SS TERM FOR GCA EFFECTS IS,E16.9)
*        740 FORMAT (1H0,25H THE EXPERIMENTAL MEAN IS,E16.9)
*        750 FORMAT (1H1,51HMATRIX INVERSE FOR DETERMINING CONFIDENCE INTERVALS
*           1)
*        760 FORMAT (1H1,64H THERE WERE RECIPROCAL CROSSES.THE ORIGINAL PLANTS
*           1 /FAMILY WERE)
*        770 FORMAT (1H1,71H THERE WERE RECIPROCAL CROSSES.THE DATA ENTERED--
*           1 MEANS OR SUMS--WERE)
*        780 FORMAT (1H1,39H THE ORIGINAL DATA ENTERED AS SUMS WERE)
*        790 FORMAT (1H1,24H THE MEAN GCA VALUES ARE)
*        800 FORMAT (1H ,5E20.9)
*        810 FORMAT (1H1,26H THE (2GCA+XBAR)VALUES ARE)
*        820 FORMAT (1H ,5E20.9)
*        830 FORMAT (1H1,20X,1HI,5X,1HJ,7X,1HN,14X,4HXBAR,14X,3HSCA//)
*        840 FORMAT (1H ,19X,I2,4X,I2,3E16.9)
*     C
*             END
```

```
C     SUBROUTINE MPRINT
C
C     THIS SUBROUTINE WILL PRINTOUT SQUARE MATRICES UP TO 50X50
C     ALL ROWS AND COLUMNS ARE APPROPRIATELY LABELED.
C     DEFINITIONS OF SUBROUTINES ARGUMENTS
C     RAY(I,J) = MATRIX TO BE PRINTED
C     M=ORDER(MAXIMUM OF 50)
C     L=1 FOR 6E20.9 OUTPUT OR 2 FOR 10F12.2
C     TI IS A SIX-CHARACTER DESIGNATE OF THE MATRIX
C
      SUBROUTINE MPRINT (RAY,M,L,TI)
      DIMENSION RAY(50,50),JJ(50)
      IF(L-1)2,2,4
    2 L1=5
      GO TO 5
    4 L1 = 9
    5 J1 = 0
      J2 = 0
      JSEC = 0
      DO 8 I= 1,M
    8 JJ(I)=I
    9 J1 = J2+1
      J2 = J1+L1
      IF(J2-M)13,13,12
   12 J2=M
   13 JSEC = JSEC + 1
      IF(JSEC - 1) 18,18,19
   18 WRITE(6 ,17) TI,JSEC
   17 FORMAT(1H0,A6,9H SECTION ,I3/)
      GO TO 201
   19 WRITE(6 ,20) TI,JSEC
   20 FORMAT(1H1,A6,9H SECTION ,I3)
  201 IF(L-1)21,21,26
   21 WRITE(6 ,22) (JJ(I), I=J1,J2)
   22 FORMAT(6H0 ROW ,3X,I12,5I20)
      DO 23 I=1,M
   23 WRITE(6,24) I, (RAY(I,K), K=J1,J2)
   24 FORMAT(I6,4X,6E20.9)
      GO TO 31
   26 WRITE(6 ,27) (JJ(I),I=J1,J2)
   27 FORMAT(6H0 ROW ,3X,10I11)
      DO 29 I=1,M
   29 WRITE(6,30) I, (RAY(I,K),K=J1,J2)
   30 FORMAT(I6,4X,10F11.4)
   31 IF(J2-M)9,32,32
   32 RETURN
      END
```

```
C       SUBROUTINE MATINV MODIFIED TO HANDLE DEPENDENCIES
C
C       PROGRAMMED BY BURTON S. GARBOW, ARGONNE NATIONAL LABORATORY,
C       AND REPORTED IN IBM 704-709 SHARE LIBRARY AS AN F402.
C
C       THIS SUBROUTINE COMPUTES THE INVERSE AND DETERMINANT OF MATRIX A,
C       OF ORDER N, BY THE GAUSS-JORDAN METHOD. A-INVERSE REPLACES A,
C       AND THE DETERMINANT OF A IS PLACED IN DETERM. IF M = 1 THE
C       VECTOR BB CONTAINS THE CONSTANT VECTOR WHEN MATINV IS CALLED,
C       AND THIS IS REPLACED WITH THE SOLUTION VECTOR. IF M = 0, NO
C       SIMULTANEOUS EQUATION SOLUTIONS ARE CALLED FOR, AND BB IS NOT
C       PERTINENT. NN IS NOT TO EXCEED 50. A, NN, BB, M, AND DETERM IN
C       THE ARGUMENT LIST ARE DUMMY VARIABLES.
C       IORDER=1  ROWS OR COLUMNS NOT REORDERED
C             =0 REORDERED
C
C
        SUBROUTINE MATINV (A,NN,BB,M,DETERM,NDEP,IORDER)
C       SUBROUTINE MATINV DIMENSION
        DIMENSION IPIVOT(50),A(50,50),BB(50,1),INDEX(50,2),PIVOT(50)
        EQUIVALENCE (IROW,JROW), (ICOLUM,JCOLUM), (AMAX, TT, SWAP)
C       INITIALIZATION
        NDEP= 0
        EPS= 1.0E-06
     10 DETERM=1.0
     15 DO 20 J=1,NN
     20 IPIVOT(J)=0
     30 DO 555 I = 1, NN
C       SEARCH FOR PIVOT ELEMENT
C       FOLLOWING ALLOWS FOR NO REORDERING
        IF(IORDER.EQ.0) GO TO 40
        IROW=I
        ICOLUM=I
        GO TO 110
     40 AMAX=0.0
     45 DO 105 J=1,NN
     50 IF(IPIVOT(J)-1) 60, 105, 60
     60 DO 100 K=1,NN
     70 IF(IPIVOT(K)-1) 80, 100, 740
     80 IF(ABS(AMAX)-ABS(A(J,K))) 85, 100, 100
     85 IROW=J
     90 ICOLUM=K
     95 AMAX=A(J,K)
    100 CONTINUE
    105 CONTINUE
    110 IPIVOT(ICOLUM)=IPIVOT(ICOLUM)+1
C       INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL
    130 IF(IROW-ICOLUM) 140, 260, 140
    140 DETERM=-DETERM
    150 DO 200 L=1,NN
    160 SWAP=A(IROW,L)
    170 A(IROW,L)=A(ICOLUM,L)
    200 A(ICOLUM,L)=SWAP
    205 IF(M) 260, 260, 210
    210 DO 250 L=1,M
    220 SWAP=BB(IROW,L)
    230 BB(IROW,L)=BB(ICOLUM,L)
    250 BB(ICOLUM,L)=SWAP
    260 INDEX(I,1)=IROW
    270 INDEX(I,2)=ICOLUM
    310 PIVOT(I)=A(ICOLUM,ICOLUM)
        IF(ABS(PIVOT(I)).GT.EPS) GO TO 320
        IF(M.NE.1) GO TO 600
        DO 3700 L=1,M
```

```
 3700 BB(ICOLUM,L)=0.
      DETERM=0
      NDEP = NDEP +1
      GO TO 555
  320 DETERM=DETERM*PIVOT(I)
C     DIVIDE PIVOT ROW BY PIVOT ELEMENT
  330 A(ICOLUM,ICOLUM)=1.0
  340 DO 350 L=1,NN
  350 A(ICOLUM,L)=A(ICOLUM,L)/PIVOT(I)
  355 IF(M) 380, 380, 360
  360 DO 370 L=1,M
  370 BB(ICOLUM,L)=BB(ICOLUM,L)/PIVOT(I)
C     REDUCE NON-PIVOT ROWS
  380 DO 550 L1=1,NN
  390 IF(L1-ICOLUM) 400, 550, 400
  400 TT=A(L1,ICOLUM)
  420 A(L1,ICOLUM)=0.0
  430 DO 450 L=1,NN
  450 A(L1,L)=A(L1,L)-A(ICOLUM,L)*TT
  455 IF(M) 550, 550, 460
  460 DO 500 L=1,M
  500 BB(L1,L)=BB(L1,L)-BB(ICOLUM,L)*TT
  550 CONTINUE
  555 CONTINUE
C     INTERCHANGE COLUMNS
  600 DO 710 I=1,NN
  610 L=NN+1-I
  620 IF(INDEX(L,1)-INDEX(L,2)) 630, 710, 630
  630 JROW=INDEX(L,1)
  640 JCOLUM=INDEX(L,2)
  650 DO 705 K=1,NN
  660 SWAP=A(K,JROW)
  670 A(K,JROW)=A(K,JCOLUM)
  700 A(K,JCOLUM)=SWAP
  705 CONTINUE
  710 CONTINUE
  740 RETURN
      END
```

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Snyder, E. B.

1975. Combining-ability determinations for incomplete mating designs. South. For. Exp. Stn., New Orleans, La. 12 p. (USDA For. Serv. Gen. Tech. Rep. SO-9)

It is shown how general combining ability values (GCA's) from cross-, open-, and self-pollinated progeny can be derived in a single analysis. Breeding values are employed to facilitate explaining genetic models of the expected family means and the derivation of the GCA's. A FORTRAN computer program also includes computation of specific combining ability values and several options.

Additional keywords: Diallel cross, reciprocal cross, specific combining ability, *panmixia*.

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Interrelationships among microorganisms, bark or ambrosia beetles, and woody host tissue: an annotated bibliography, 1965-1974

S.J. Barras and T.J. Perry

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INTERRELATIONSHIPS AMONG MICROORGANISMS, BARK OR AMBROSIA BEETLES, AND WOODY HOST TISSUE: AN ANNOTATED BIBLIOGRAPHY, 1965-1974

S. J. Barras and T. J. Perry[1]

Of the many factors that influence the development of scolytids within woody hosts, the east understood are the interrelationships of insects, microorganisms, and host trees. Only imited information is available concerning the biological, ecological, and physiological parameters of the associations, but the final result is the destruction of valuable timber resources. Broad classes of symbiosis have recently been recognized but are still not fully understood. Symbiosis here denotes not only direct interactions between insects and microorganisms but also refers to microorganism-woody tissue interactions that often influence insect development and survival.

By compiling this bibliography, we hope to timulate further research into these interrelaionships, which must be comprehended before a thorough understanding of scolytid development is possible. The bibliography represents a collection of articles and abstracts from many isciplines; the entries were compiled both during our own research and after an extensive reiew.

We included papers and abstracts about the iology and physiology of specific microorganisms (bacteria, yeasts, and fungi) associated with bark and ambrosia beetles and items concerning the maintenance of these associations. Also included are papers about pathogenic associations, nutrition, and other biochemical interactions. Microbial taxonomic papers are presented only to provide information on the synonomy of organisms.

We have included pertinent literature published since Francke-Grosmann's 1967 review "Ectosymbiosis in Wood Inhabiting Insects." Papers published before 1967 but not included in her review are also cited. We have excluded literature related to Dutch elm disease because of previous extensive reviews (Laut and Schomaker 1974, Peacock 1973).[2]

All articles and abstracts were examined in entirety—either as originally printed or as reprints or copies. When available, abstracts of the papers were reviewed to determine their suitability for this publication and were revised or expanded to satisfy the requirements of an annotated bibliography. The entries and the index are as comprehensive as possible to offer readers of various interests a system for identifying pertinent information. We hope that researchers in diverse fields will find the bibliography useful.

We regret inadvertent omissions and would welcome having them called to our attention.

1. Abrahamson, L. P., H-M Chu, and D. M. Norris. 1967. SYMBIONTIC INTERRELATIONSHIPS BETWEEN MICROBES AND AMBROSIA BEETLES. II. THE ORGANS OF MICROBIAL TRANSPORT AND PERPETUATION IN *TRYPODENDRON BETULAE* AND *T. RETUSUM* (COLEOPTERA: SCOLYTIDAE). Ann. Entomol. Soc. Am. 60: 1107–1110.

   Mycangia were the prothoracic-pleural type and resembled those of other Trypodendron *species. Secretions released into the mycangium may contribute to ambrosia cell growth in symbiontic fungi.*

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[1] Barras is research entomologist and Perry is biological technician, Forest Service—USDA, Southern Forest Experiment Station, Pineville, La. The authors acknowledge the assistance of Michael Dunn in preparing the bibliography and thank Dr. H. S. Whitney and Dr. R. C. Wilkinson for reviewing the manuscript.

[2] Laut, J. G. and M. E. Shomaker. Dutch elm disease—a bibliography. Colorado State Forest Service, Colorado State University. 95 p. 1974.

Peacock, J. W. Research on chemical and biological controls for elm bark beetles. Proc. IUFRO Meeting on Dutch Elm Disease. St. Paul, Minn. (in press). 1973.

2. Abrahamson, L. P., and D. M. Norris. 1966. THE MYCANGIA OF *XYLOTERINUS POLITUS* (SAY). Univ. Wisc. For. Res. Note 129, 4 p.
   Two distinct pairs of mycangia were found in adults. One was a prothoracic-pleural type found only in females, and the other opened into oral cavities of both sexes.

3. Abrahamson, L. P., and D. M. Norris. 1966. SYMBIONTIC INTERRELATIONSHIPS BETWEEN MICROBES AND AMBROSIA BEETLES. I. THE ORGANS OF MICROBIAL TRANSPORT AND PERPETUATION OF *XYLOTERINUS POLITUS*. Ann. Entomol. Soc. Am. 59: 877–880.
   Reports more details about mycangia. Different fungi were isolated from each type of mycangia (see Abrahamson and Norris, No. 2 above). A complex of fungi is involved in the nutritional utilization of natural wood substrates.

4. Abrahamson, L. P., and D. M. Norris. 1969. SYMBIONTIC INTERRELATIONSHIPS BETWEEN MICROBES AND AMBROSIA BEETLES. IV. AMBROSIAL FUNGI ASSOCIATED WITH *XYLOTERINUS POLITUS*. J. Invertebr. Pathol. 14: 381–385.
   Two primary ambrosia fungi from mycangia of X. politus *were isolated and described. One was cultured from the oral mycangia of both male and female adults and was tentatively identified as a new species of* Raffaelea. *The other was from the prothoracic-pleural mycangia of the female only and was not identified.*

5. Abrahamson, L. P., and D. M. Norris. 1970. SYMBIONTIC INTERRELATIONSHIPS BETWEEN MICROBES AND AMBROSIA BEETLES (COLEOPTERA: SCOLYTIDAE). V. AMINO ACIDS AS A SOURCE OF NITROGEN TO THE FUNGI IN THE BEETLE. Ann. Entomol. Soc. Am. 63: 177-180.
   Nonprotein acids in the adult female of Xyleborus ferrugineus *were qualitatively similar to those in most endopterygotes. Proline, valine, and alanine were the major constituents in the free amino acid pool. The soluble peptide and amide portion contained relatively large quantities of threonine and valine. Glycine was the most abundant amino acid in the protein residue.*

6. Andrieu, S., J. Biguet, and S. Massamba. 1971. ETUDE IMMUNOLOGIQUE COMPAREE DE *SPOROTHRIX SCHENCKII* ET DES SOUCHES SAPROPHYTES VOISINES. [A COMPARATIVE IMMUNOLOGICAL STUDY OF *SPOROTHRIX SCHENCKII* AND OF RELATED SAPROPHYTIC STRAINS.] Sabouraudia 9: 206-209.
   Strains of fungi with Sporothrix *conidial arrangement were taken from human sporotrichosis or from natural habitats and were compared by agar-gel precipitation. Three strains from natural habitats produced a* Ceratocystis *sexual form.* C. stenoceras *is a perfect state of* S. schenckii, *which causes sporotrichosis.*

7. Arx, J. A. von, and G. L. Hennebert. 1965. DEUX CHAMPIGNONS AMBROSIA. [TWO AMBROSIA FUNGI.] Mycopathol. Mycol. Appl. 25: 309–315.
   Describes a new genus, Raffaelea. R. ambrosiae *from galleries of* Platypus cylindrus *is the fungus originally described as* Sporothrix *sp. Also discusses the association between* Ambrosiella xylebori *and* Xyleborus compactus.

8. Ashraf, M., and A. A. Berryman. 1969. BIOLOGY OF *SCOLYTUS VENTRALIS* (COLEOPTERA: SCOLYTIDAE) ATTACKING *ABIES GRANDIS* IN NORTHERN IDAHO. Melanderia 2: 1–23.
   Aspergillus flavus *and* Penicillium *sp. were isolated from parent galleries and larval mines.* A. flavus *was also isolated from dead larvae. It was not determined if these fungi were saprophagous or entomophagous.*

9. Baker, J. M., and D. M. Norris. 1968. A COMPLEX OF FUNGI MUTUALISTICALLY INVOLVED IN THE NUTRITION OF THE AMBROSIA BEETLE *XYLEBORUS FERRUGINEUS*. J. Invertebr. Pathol. 11: 246–250.
   Paired oral mycangia present in both sexes of stock culture beetles contained a complex of fungi, yeast, and bacteria. Fusarium solani *was the dominant fungal symbiote, but a* Cephalosporium *sp. and a* Graphium *sp. were also isolated. Each fungus grew as ambrosial propagules that either provided nutrients not already present in the diet or concentrated nutrients essential to reproduction.*

10. Barras, S. J. 1967. THORACIC MYCANGIUM OF *DENDROCTONUS FRONTALIS* (COLEOPTERA: SCOLYTIDAE) IS SYNONYMOUS WITH A SECONDARY FEMALE CHARACTER. Ann. Entomol. Soc. Am. 60: 486–487.
    A transverse ridge or callus on the surface of the exoskeleton covers the outer wall of the mycangium and extends around the pronotum like a collar. The mycangium is a useful female sex character for callow and mature adults.

11. Barras, S. J. 1970. ANTAGONISM BETWEEN *DENDROCTONUS FRONTALIS* AND THE FUNGUS *CERATOCYSTIS MINOR*. Ann. Entomol. Soc. Am. 63: 1187–1190.
    In the laboratory, C. minor *acting alone was detrimental to* D. frontalis *development in loblolly pine bolts. In nature, interactions of other beetle-associated microorganisms and* C. minor *may inhibit the antagonism.*

12. Barras, S. J. 1973. REDUCTION OF PROGENY AND DEVELOPMENT IN THE SOUTHERN PINE BEETLE FOLLOWING REMOVAL OF SYMBIOTIC FUNGI. Can. Entomol. 105: 1295–1299.
    In loblolly pine bolts, lack of mycangial fungi or of the normal complement of mycangial and ectodermal fungi caused a significant decrease in number of progeny, progeny per gallery, progeny per cm of gallery, and ratio of increase. Initial emergence of progeny was delayed 13 to 24 days. Absence of fungi had no effect on the number of successful attacks, the length of ovipositional gallery, and the number of egg niches per cm of gallery.

13. Barras, S. J., and J. D. Hodges. 1969. CARBOHYDRATES OF INNER BARK OF *PINUS*

TAEDA AS AFFECTED BY *DENDROCTONUS FRONTALIS* AND ASSOCIATED MICROORGANISMS. Can. Entomol. 101: 489–493.
Glucose, fructose, and sucrose were the only sugars detected in inner bark treated with a southern pine beetle-microorganism complex and two beetle-associated fungi. C. minor *caused a 68 percent decrease in reducing sugars after 16 days, but a basidiomycete mycangial fungus required 36 days to cause a 64 percent reduction. A similar decrease in sucrose was observed. Results indicated that both fungi influenced the carbohydrate pool available to the insect, but* C. minor *had a more rapid effect on the C:N ratio.*

. Barras, S. J., and T. Perry. 1971. *LEPTOGRAPHIUM TEREBRANTIS* SP. NOV. ASSOCIATED WITH *DENDROCTONUS TEREBRANS* IN LOBLOLLY PINE. Mycopathol. Mycol. Appl. 43: 1–10.
A Leptographium *fungus associated with the black turpentine beetle* (D. terebrans) *is described for the first time. The name* Leptographium terebrantis *sp. nov. is proposed.*

. Barras, S. J., and T. Perry. 1971. GLAND CELLS AND FUNGI ASSOCIATED WITH PROTHORACIC MYCANGIUM OF *DENDROCTONUS ADJUNCTUS* (COLEOPTERA: SCOLYTIDAE). Ann. Entomol. Soc. Am. 64: 123–126.
Females have a well-developed mycangium and males, a pseudomycangium. Two types of gland cells were associated with the mycangium: one had an efferent cuticular tubule previously unreported but similar to Tenebrionidae defensive gland cells; the other was a columnar cell found previously with other mycangia. A Verticicladiella *sp. near* huntii *was contained by 60 percent of the female mycangia but was not associated with the male pseudomycangia.* Penicillium decumbens, P. spinulosum, *and yeasts were associated with both males and females.*

. Barras, S. J., and T. Perry. 1972. FUNGAL SYMBIONTS IN THE PROTHORACIC MYCANGIUM OF *DENDROCTONUS FRONTALIS* (COLEOPTERA: SCOLYTIDAE). Z. Angew. Entomol. 71: 95–104.
An undescribed Sporothrix *and a basidiomycete were the predominant fungi in the attacking female. Other microorganisms such as* Ceratocystis minor, Penicillium *spp., and yeasts may occasionally occur in callow adults, but only yeasts were still present in attacking beetles. The chemical regime of the mycangium selectively favors* Sporothrix *sp. and the basidiomycete.* Sporothrix *isolate is a highly modified anascigerous form of* Ceratocystis.

7. Barras, S. J., and J. J. Taylor. 1973. VARIETAL *CERATOCYSTIS MINOR* IDENTIFIED FROM MYCANGIUM OF *DENDROCTONUS FRONTALIS*. Mycopathol. et Mycol. Appl. 50: 293–305.
A detailed description of the fungus and a discussion of its symbiotic relationship to the insect. A fungus in the adult female produced an anascigerous Sporothrix *sp. in various media. After prolonged growth on potato glucose agar, the fungus produced a type of* Ceratocystis minor.

18. Basham, H. G. 1968. PATHOGENICITY OF SOME BLUE-STAIN FUNGI IN THE GENUS CERATOCYSTIS. Phytopathology 58: 1042.
Abstract of paper for American Phytopathological Society. Loblolly pines were inoculated with pure cultures of Ceratocystis *species. Several pathogenic isolates of* C. ips, C. minor, C. montia, *and* C. pilifera *caused a penetrating stain in sapwood and killed trees. All except* C. pilifera *are associated with pine bark beetles. Dye conduction tests revealed no dye in stained sapwood of dead seedlings.*

19. Basham, H. G. 1970. WILT OF LOBLOLLY PINE INOCULATED WITH BLUE-STAIN FUNGI OF THE *GENUS CERATOCYSTIS*. Phytopathology 60: 750–754.
Pathogenicity of C. ips, C. minor, C. montia, *and* C. pilifera *appeared related to their capacities to penetrate living sapwood. Blockage of water conduction caused wilting. Vigor of the saplings, as measured by crown class or stem diameter, appeared inversely related to susceptibility to pathogenic isolates. A zone of phenols and resins was noted in the region of fungal invasion of resistant trees but not in trees killed by the fungi.*

20. Batra, L. R. 1963. ECOLOGY OF AMBROSIA FUNGI AND THEIR DISSEMINATION BY BEETLES. Trans. Kans. Acad. Sci. 66: 213–236.
Discusses mycangia as repositories for plant pathogens and the role of the ambrosial mass in insect nutrition. Ambrosia fungi were associated with 20 beetle species. Both the specific and dominant ambrosia fungus and propagative bodies of nonspecific fungi were present in insect tunnels. Most foreign fungi were the yeasts and yeast allies Ceratocystis *spp.,* Fusarium *spp.,* Aspergillus, Penicillium, *and* Trichoderma lignorum. *Ambrosia fungi were stored in mycangia during hibernation and disseminated during burrowing in early spring. Ambrosia cells from tunnels and mycangia of related beetles were morphologically similar but showed cultural differences. Limited multiplication of fungi occurred in the mycangia of some beetles.*

21. Batra, L. R. 1966. AMBROSIA FUNGI: EXTENT OF SPECIFICITY TO AMBROSIA BEETLES. Science 153: 193–195.
Beetles may feed on more than one species. Yeast-like ambrosia propagules in the mycangia are from conidia and ascospores picked up by callow adults while in the tunnels.

22. Batra, L. R. 1967. AMBROSIA FUNGI: A TAXONOMIC REVISION, AND NUTRITIONAL STUDIES OF SOME SPECIES. Mycologia 59: 976–1017.
Provides keys to genera and species of all known ambrosia fungi associated with ambrosia beetles. The ambrosia phase occurs in insect tunnels and mycangia of Scolytidae, Platypodidae, and Lymexylidae (Coleoptera). Primary ambrosia fungi belong to four genera of Tuberculariaceae (Ambrosiella, Raffaelea, Monacrosporium, *and* Phial-

ophoropsis) *and two of Endomycetales* (Ascoidea *and* Endomycopsis).

23. Batra, L. R. 1971. TWO NEW HEMIASCOMYCETES: *PICHIA CROSSOTARSI* AND *P. MICROSPORA*. Mycologia 63: 994-1001.

    Gives cultural and taxonomic characteristics of two new species found in association with the ambrosia beetle Crossotarsus wollastoni *from Kakanakote, Mysore, India. The yeasts may be an auxiliary source of nutrition. Cultural and taxonomic characteristics of the yeasts are presented.*

24. Batra, L. R. 1972. ECTOSYMBIOSIS BETWEEN AMBROSIA FUNGI AND BEETLES—I. Ind. J. Mycol. Plant Pathol. 2: 165–169.

    Reviews previously described associations between ambrosia beetles and fungi. Describes primary and auxiliary ambrosia fungi and discusses specificity of associations. Ectosymbiosis represents a mutualistic mode of life where one symbiont cannot live without the other.

25. Beanlands, G. E. 1967. THE EFFECTS OF BARK MOISTURE ON *POLYGRAPHUS RUFIPENNIS* (COLEOPTERA: SCOLYTIDAE) ADULTS AND THEIR DEVELOPING BROODS. Can. Entomol. 99: 561–564.

    Adults and immature stages reared in white spruce bark with high moisture levels had decreased survival and rate of development after 40 days. High moisture may have increased fungal growth and the rate of bark decomposition.

26. Becker, G. 1971. PHYSIOLOGICAL INFLUENCES ON WOOD-DESTROYING INSECTS OF WOOD COMPOUNDS AND SUBSTANCES PRODUCED BY MICROORGANISMS. Wood Sci. and Technol. 5: 236–246.

    Describes reactions of various species of Coleoptera and Isoptera to attractive or repellent compounds in wood species or substances produced by fungi. Insect nutrition depends on wood nitrogen compounds, which can be increased by the presence of fungi.

27. Berryman, A. A. 1969. RESPONSES OF *ABIES GRANDIS* TO ATTACK BY *SCOLYTUS VENTRALIS* (COLEOPTERA: SCOLYTIDAE). Can. Entomol. 101: 1033–1041.

    Resistant trees produced secondary resin in cells of the phloem parenchyma and formed callus tissue and traumatic resin cavities at the cambium-sapwood interface. Vulnerable trees had limited resinosis that could not prevent invasion by the insect-fungus complex.

28. Berryman, A. A. 1972. RESISTANCE OF CONIFERS TO INVASION BY BARK BEETLE-FUNGUS ASSOCIATIONS. BioScience 22: 598–602.

    Discusses mainly western bark beetles with limited information on mycangia. Infection of the inner bark or cambium produces a resistant or hypersensitive reaction causing a wound periderm to form around the necrotic lesion. Resistant trees may produce compounds toxic to fungi (terpenes, polyphenols). Callus formations contain traumatic resin canals or cavities that eventually curtail the fungus. Failure of the hypersensitivity reaction causes massive necrosis of host tissue and may kill the tree.

29. Bevan, D. 1962. THE AMBROSIA BEETLE OR PINHOLE BORER *TRYPODENDRON LINEATUM* OL. Scot. For. 16: 94–99.

    In conifer logs of western Scotland, the ambrosia fungus (unidentified) that provides food for the brood is inoculated into tunnels by the female at the time of gallery construction. The originally white mycelium turns black in the entrance and main tunnel after the eggs hatch; then the larval niches change color. Following pupation, tending parents leave, having kept the gallery clean for larvae by cropping back the fungus.

30. Biévre, C. de, and C. Jourd'huy. 1974. ETUDE COMPARATIVE DES PHOSPHOLIPIDES DE PLUSIEURS SOUCHES DE *CERATOCYSTIS STENOCERAS* ET DE *SPOROTHRIX SCHENCKII*. [COMPARATIVE STUDY OF THE PHOSPHOLIPIDS FROM SEVERAL FORMS OF *C. STENOCERAS* AND OF *S. SCHENCKII*.] C. R. Acad. Sci. Paris Ser. D. 278: 53–55.

    Characterizes phospholipids from several forms of C. stenoceras *(wild and mutant sources) and* S. schenckii. *Phospholipid compositions indicate similarity between the two species. All fungal stocks contained cardiolipin, phosphatidylethanolamine, phosphatidyl N methylethanolamine, phosphatidylserine, phosphatidylcholine, lysophosphatidylethanolamine, and lysophosphatidylcholine. The wild source (asigerous) of* C. stenoceras *(1013) contained some phosphatidylinositol; anasigerous mutants (parasitic and nonparasitic) and* S. schenckii *did not.*

31. Bletchly, J. D., and M. G. White. 1962. SIGNIFICANCE AND CONTROL OF ATTACK BY THE AMBROSIA BEETLE *TRYPODENDRON LINEATUM* (OLIV.) (COL. SCOLYTIDAE) IN ARGYLLSHIRE FORESTS. Forestry 35: 139–163.

    Parent beetles introduce spores of specialized fungi where eggs are laid to provide the major part of brood nutrition. Fungi can survive only when wood remains green. In processed logs, both fungi and larvae die as timber dries.

32. Borden, J. H., and M. McClaren. 1970. BIOLOGY OF *CRYPTOPORUS VOLVATUS* (PECK) SHEAR (AGARICALES, POLYPORACEAE) IN SOUTHWESTERN BRITISH COLUMBIA: DISTRIBUTION, HOST SPECIES, AND RELATIONSHIP WITH SUBCORTICAL INSECTS. Syesis 3: 145–154.

    Occurs primarily where annual rainfall is less than 60 inches. Main host trees are Pseudotsuga menziesii *and* Pinus ponderosa, *but the fungus was also found on* Pinus contorta *and* Abies amabilis, *which is a new host record. Both occurrence and density were strongly correlated with Douglas-fir beetle* (Dendroctonus pseudotsugae) *attacks on host trees the previous year.* Temnochila virescens var. chlorodia, *a predator of subcortical insects, is probably a vector of* C. volvatus.

3. Brader, L. 1965. BETEKENIS VAN DE AMBROSIA-SCHIMMEL VOOR DE ONTWIKKELING VAN *XYLEBORUS COMPACTUS* EICHH., DE ZWARTE TAKKENBOORDER VAN KOFFIE (COLEOPTERA, SCOLYTIDAE). [IMPORTANCE OF AMBROSIA FUNGI FOR THE DEVELOPMENT OF *XYLEBORUS COMPACTUS* EICHH., THE BLACK COFFEE TWIG BORER.] Entomol. Ber. 25: 32.
Biology, symbiosis.

4. Bright, D. E., Jr. 1968. REVIEW OF THE TRIBE XYLEBORINI IN AMERICA NORTH OF MEXICO (COLEOPTERA: SCOLYTIDAE). Can. Entomol. 100: 1288–1323.
All are ambrosia beetles. Adults bore into woody tissues of host plants and feed on the ambrosial fungi lining tunnel walls. Coniferous and deciduous trees and shrubs of all sizes are attacked.

5. Bright, D. E., Jr., and R. W. Stark. 1973. THE BARK AND AMBROSIA BEETLES OF CALIFORNIA. COLEOPTERA: SCOLYTIDAE AND PLATYPODIDAE. Bull. Calif. Insect Surv. 16, 169 p. Univ. Calif. Press, Berkeley.
Limited information on the following beetle-fungus associations: Platypus wilsoni-Tuberculariella ambrosiae, Scolytus ventralis-Trichosporium symbioticum, Dendroctonus brevicomis-*blue stain fungus,* Trypodendron lineatum-Monilia ferruginea, Xyleborus dispar-*ambrosial fungus,* X. saxeseni-*ambrosial fungus,* Monarthrum scutellare-Monilia brunnea *and* Gnathotrichus sulcatus-*ambrosial fungus.*

6. Buchner, P. 1965. ENDOSYMBIOSIS OF ANIMALS WITH PLANT MICROORGANISMS (TRANSL. FROM GERMAN). 909 p. John Wiley and Sons, Inc., New York.
Reviews and updates early literature of insect-fungus transmission devices and insect-associated symbionts. Discusses Coleopterous bark-boring beetles Myelophilus minor, Ips acuminatus, Trypodendron, Xylosandrus, Anisandrus dispar, Xyleborus fornicatus, X. mascarensis, X. pfeili, Hylecoetus dermestoides, H. lugubris, Platypus cylindrus, Scolytus *and* Dendroctonus. *The bacterial symbionts in mycetocytes of the Ipidae showed significant form differences that varied according to mycetocyte location.*

7. Butin, H., and G. Zimmerman. 1972. ZWEI NEUE HOLZVERFÄRBENDE *CERATOCYSTIS*-ARTEN IN BUCHENHOLZ (*FAGUS SYLVATICA* L.). [TWO NEW WOOD STAIN *CERATOCYSTIS*-ARTEN IN BEECHWOOD (*FAGUS SYLVATICA* L.).] Phytopathol. Z. 74: 281–287.
Description of two new species isolated from galleries of Xyloterus domesticus. C. bacillospora *sp. nov. is characterized by rod-shaped spores;* C. torulosa *sp. nov. is similar to* C. distorta, *but sizes of ascospores and* Cladosporium-*like conidia differ. Both ascomycetes cause light brown discoloration of beechwood.*

8. Campbell, R. N. 1958. NUTRIENT REQUIREMENTS FOR THE PRODUCTION OF PERITHECIA BY *CERATOCYSTIS VARIOSPORA* AND OTHER SPECIES. Am. J. Bot. 45: 263–270.
Abundant perithecia resulted when the ratio of nitrogen in asparagine and calcium nitrate mixtures was 1:3. The fungus can utilize nitrate nitrogen when an organic nitrogen source furnishing an amino or amide group is available for the formation of essential amino acid precursors. C. pluriannulata, C. piceae, C. pilifera, *and* C. ips *produced more perithecia on the asparagine-nitrate medium than on the asparagine or calcium nitrate media;* C. coerulescens *produced fewer perithecia than the others.*

39. Chansler, J. F., and D. A. Pierce. 1966. BARK BEETLE MORTALITY IN TREES INJECTED WITH CACODYLIC ACID (HERBICIDE). J. Econ. Entomol. 59: 1357–1359.
Fast acting herbicides containing cacodylic acid (dimethylarsenic acid) significantly reduced broods of Dendroctonus adjunctus, D. obesus, *and* D. ponderosae *in naturally infested trees. The chemical was injected directly into the sap stream near ground level. Application was made soon after the attack before most of the eggs had hatched.*

40. Chapman, J. A. 1965. A REVIEW OF THE RELATIONSHIPS BETWEEN FUNGI AND SCOLYTID BEETLES—A SUMMARY. Pages 32-38 *in* Proc. 13th West. Int. For. Dis. Work Conf., Kilowna, B. C.
Briefly reviews bark and ambrosia beetles known to have specific associations with microorganisms and shows need for more information. The symbiotic relationship between the ambrosia beetle and its fungus should be demonstrated by removing the fungus from the insect and subsequently replacing it. The relationship between bark beetles and blue stain fungi is not presently understood.

41. Chapman, J. A., S. H. Farris, and J. M. Kinghorn. 1963. DOUGLAS-FIR SAPWOOD STARCH IN RELATION TO LOG ATTACK BY THE AMBROSIA BEETLE, *TRYPODENDRON*. For. Sci. 9: 430–439.
Both attacked and unattacked logs contain little or no starch. Immature and adult beetles feed primarily on a symbiotic fungus, which utilizes starch, sugars, or other nutritional substances in wood cells. Discusses assumption that beetles have evolved a behavior pattern for selecting logs suitable for fungal growth.

42. Chu, H-M, D. M. Norris, and L. T. Kok. 1970. PUPATION REQUIREMENT OF THE BEETLE, *XYLEBORUS FERRUGINEUS*: STEROLS OTHER THAN CHOLESTEROL. J. Insect Physiol. 16: 1379–1387.
Aposymbiotic insects that utilized cholesterol or lanosterol as the sole sterol source for producing eggs and initial larval growth failed to pupate during consecutive broods. When ergosterol or 7-dehydrocholesterol was the only sterol source, insects consistently produced normal progeny. The insect feeds naturally on symbiotic fungi that contain ergosterol. Lumisterol and vitamins D_2 *and* D_3 *were antagonistic to progeny production and survival. At the* C_{16} *position, the three chemicals differed from acceptable sterols.*

43. Cobb, F. W., Jr., M. Krstic, E. Zavarin, and H. W. Barber, Jr. 1968. INHIBITORY EFFECTS OF VOLATILE OLEORESIN COMPONENTS ON *FOMES ANNOSUS* AND FOUR *CERATOCYSTIS* SPECIES. Phytopathology 58: 1327–1335.
    Constituents from ponderosa pine oleoresin reduced growth of C. minor, C. schrenkiana, C. pilifera, *and* F. annosus, *but not of* C. ips. *Colony character, pigmentation, and sporulation were also affected. When fungi were removed from vapors other than heptane, the colonies grew normally. Inhibition was sometimes greater when components were incorporated in the substrate. Effects on spore germination were not as great as on germ tube elongation. Terpene components may influence tree resistance to infection, especially in conjunction with accumulation of phenols.*

44. Cobb, F. W., Jr., and W. D. Platt. 1967. PATHOGENICITY OF *VERTICICLADIELLA WAGENERII* TO DOUGLAS FIR. Phytopathology 57: 998–999.
    Fungal isolates from Douglas-fir and ponderosa pine can infect seedlings of both species. Severe foliage discoloration was noted in pine. The xylem discoloration pattern tends to follow the annual rings vertically and tangentially, but not radially as do blue-stain fungi.

45. Coulson, R. N., T. L. Payne, J. E. Coster, and M. W. Houseweart. 1972. THE SOUTHERN PINE BEETLE *DENDROCTONUS FRONTALIS* ZIMM. (COLEOPTERA: SCOLYTIDAE) 1961-1971. Tex. For. Serv. Publ. 108, 38 p.
    Reviews 11 references on microbes.

46. Crane, J. L., and J. D. Schoknecht. 1973. CONIDIOGENESIS IN *CERATOCYSTIS ULMI*, *CERATOCYSTIS PICEAE*, AND *GRAPHIUM PENICILLIOIDES*. Am. J. Bot. 60: 346–354.
    Establishes the new hypomycete genus Pesotum *for* C. ulmi *(associated with* Scolytus multistriatus*) and* C. piceae, *based on their conidial states. Rejects the lectotype specimen* Graphium penicillioides *as the conidial state.*

47. Curtis, C. R. 1967. RESPONSE OF FUNGI TO DIURNAL TEMPERATURE EXTREMES. Nature 213: 738–739.
    Several species were treated to diurnal temperatures of -94°C to 23 ± 2°C for 35 days to simulate Martian extremes. The Ceratocystis *spp. showed no growth on soil plates during testing but afterwards developed on potato dextrose agar at 25°C and did not differ morphologically from stock cultures. Names no species.*

48. Davidson, R. W. 1966. NEW SPECIES OF *CERATOCYSTIS* FROM CONIFERS. Mycopathol. Mycol. Appl. 28: 273–286.
    Four of five new species were associated with bark beetles: Ceratocystis abiocarpa *from galleries of* Ips *sp. in Engelmann spruce and* Dryocoetes *sp. in subalpine fir;* C. nigrocarpa *in logs infested with* Scolytus *sp., on late larvae of* Dendroctonus brevicomis *in ponderosa pine logs, and on adults of* I. oregoni; C. leucocarpa *in* Ips *galleries in sugar pine and in dead ponderosa pine; and* C. minutabicolor *in* Ips *spp. galleries in spruce, firs, pines, and other conifers. The fifth species,* C. seticollis, *was isolated only once—from ambrosia beetle galleries in a hemlock stump.*

49. Davidson, R. W. 1971. NEW SPECIES OF *CERATOCYSTIS*. Mycolgia 63: 5–15.
    Five were isolated: Ceratocystis francke-grosmanniae *from larval galleries of* Hylecoetus dermestoides *in oak from Germany,* C. olivaceapini *from* Dendroctonus *sp. on ponderosa pines in Arizona and New Mexico,* C. distorta *from ambrosia beetles occasionally infesting spruce and fir in North America,* C. gossypina *from insect galleries in pines from North America, and* C. sparsa *from bark beetle galleries in white spruce from Alaska.* Ceratocystis gossypina *var.* robusta *was isolated from insect-infested pine in southern New Mexico.*

50. Davidson, R. W., H. Francke-Grosmann, and A. Käärik. 1967. A RESTUDY OF *CERATOCYSTIS PENICILLATA* AND REPORT OF TWO AMERICAN SPECIES OF THIS GENUS FROM EUROPE. Mycologia 59: 928–932.
    C. penicillata *from* Ips typographus *was different from both* C. europhioides *and* C. huntii. C. bicolor *was isolated from* Ips*-infested spruce logs near Stockholm, Sweden.*

51. Davidson, R. W., and R. C. Robinson-Jeffrey. 1965. NEW RECORDS OF *CERATOCYSTIS EUROPHIOIDES* AND *C. HUNTII* WITH *VERTICICLADIELLA* IMPERFECT STAGES FROM CONIFERS. Mycologia 57: 488–490.
    Gives extended ranges for the species and presents further records for association of C. huntii *with* Ips pini *and* Dendroctonus *species.*

52. DeGroot, R. C. 1972. GROWTH OF WOOD-INHABITING FUNGI IN SATURATED ATMOSPHERES OF MONOTERPENOIDS. Mycologia 64: 863–870.
    Three wood-decay fungi (Lenzites saepiaria, Peniophora gigantea, *and* Schizophyllum commune), *one blue-stain fungus* (Ceratocystis minor), *and one deuteromycete* (Trichoderma viride) *were grown in l-α-pinene, d-α-pinene, l-limonene, d-limonene, p-cymene, dl-camphene, mycrene l-β-pinene, and terpinolene.* C. minor *was inhibited the least by all but p-cymene (not present in living pines) and terpinolene;* T. viride *was inhibited the most. Natural selection for terpene-tolerant variants of the fungi may occur. D-α-pinene limits invasion of southern pine sapwood by* C. minor.

53. DeMars, C. J., Jr., D. L. Dahlsten, and R. W. Stark. 1970. SUVIVORSHIP CURVES FOR EIGHT GENERATIONS OF THE WESTERN PINE BEETLE IN CALIFORNIA, 1962-1965, AND A PRELIMINARY LIFE TABLE. Pages 134-146 *in* Studies of the Population Dynamics of the Western Pine Beetle, *Dendroctonus brevicomis* LeConte (Coleopetera: Scolytidae). Edited by R. W. Stark and D. L. Dahlsten. Univ. Calif. Div. Agric. Sci., Berkeley.
    Diseased insects were not prevalent, but Beauveria bassiana *and an* Isaria *sp. were isolated from dead larvae and may have caused some of the unexplained mortality.*

54. Doane, C. C. 1959. *BEAUVERIA BASSIANA* AS A PATHOGEN OF *SCOLYTUS MULTISTRIATUS*. Ann. Entomol. Soc. Am. 52: 109–111.
Most frequently encountered pathogen. Infected up to 6.5 percent of overwintering larvae in trees and killed 97 percent of the larvae in one epizootic. In the laboratory, 99 percent of the larvae died in 5 days.

55. Doane, C. C. 1960. BACTERIAL PATHOGENS OF *SCOLYTUS MULTISTRIATUS* MARSHAM AS RELATED TO CROWDING. J. Insect Pathol. 2: 24–29.
One to four "last stage larvae" per unit space were confined on bark treated with Serratia marcescens *or sterile water. Mortality increased with number of larvae per unit space in both treated and untreated bark. Untreated larvae usually died from bacteria already on the integument. In 3 days, mortality of treated larvae (4 per unit space) was 92 percent, and control mortality was about 60 percent. Two other bacteria,* Aerobacter scolyti *and* Escherichia klebsiellaeformis, *caused comparable mortality in identical tests.*

56. Dowding, P. 1969. THE DISPERSAL AND SURVIVAL OF SPORES OF FUNGI CAUSING BLUESTAIN IN PINE. Trans. Br. Mycol. Soc. 52: 125–137.
Airborne dispersal is probably not responsible for most infections. Conidia of Ceratocystis *spp. (including* C. minor*) were rarely dislodged from their sticky heads by dry air currents but were readily dislodged by and carried on mist and splash droplets. Ascospores were carried only as large discrete masses in a few splash droplets. Conidia separated in water but lost viability rapidly on exposure to sunlight, ultraviolet light, and humidities below 95 percent r.h. An outer shell of dried spores and mucilage protected the inner mass of spores from desiccation and provided some protection from irradiation.*

57. Dowding, P. 1970. COLONIZATION OF FRESHLY BARED PINE SAPWOOD SURFACES BY STAINING FUNGI. Trans. Br. Mycol. Soc. 55: 399–412.
Ceratosystis *spp. (including* C. minor*) produced few air-borne spores. Most transmission to host tissue is by animal vectors—often bark beetles. Spores must be carried into sites protected from ultraviolet light and desiccation.*

58. Eckersley, A. M. 1934. SOME SAP-STAINING ORGANISMS OF *PINUS RADIATA*, D. DON, IN VICTORIA, AUSTRALIA. Proc. R. Soc. Victoria 46: 179–194.
Describes two forms of Ceratostomella (= Ceratocystis) *that may link the American* C. pilifera *with the European* C. coerulea, *both of which may be variants of the same species,* C. coerulea.

59. Entwistle, P. F. 1964. INBREEDING AND ARRHENOTOKY IN THE AMBROSIA BEETLE *XYLEBORUS COMPACTUS* (EICHH.) (COLEOPTERA: SCOLYTIDAE). Proc. R. Entomol. Soc. Lond. Series A. 39(4-6): 83–88.
Galleries are initiated by single adult females and differ in form according to host plant species. Eggs are laid over an extended period, and larvae feed on an ambrosia fungus that grows on gallery walls and that develops communally with eggs and pupae.

60. Eusebio, M. A. 1968. GROWTH OF FIVE STAINING FUNGI AND STAIN DEVELOPMENT IN PINE SAPWOOD. Philipp. J. For. 20: 69–91.
Estimated optimum temperatures for growth on malt agar and blocks of white pine were 24° C for Ceratocystis coerulea, Leptographium lundbergii, Alternaria tenuis, *and* Cytospora pini, *and 28° C for* Ceratocystis ips. *Fungi developed primarily in parenchyma cells, but at the ray crossing, the mycelium passed through the parenchyma walls and through pits in the adjacent tracheids to reach the lumens.*

61. Farmer, L. J. 1965. THE PHLOEM-YEAST COMPLEX DURING INFESTATIONS OF THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE. Diss. Abstr. 26: 1304–1305.
A phloem-yeast complex including at least four species comprises food for developing larvae of Dendroctonus ponderosae. *Economically damaging outbreaks of the beetle will not occur without the complex, since larvae feed only in yeast-infected areas. Yeasts may rapidly convert host material to simpler molecules, such as amino acids and vitamins, needed in the larval diet. Eight yeast were isolated from the lodgepole pine-mountain pine beetle complex:* Hansenula holstii *and* Pichia pini, *found in phloem and on larvae;* H. capsulata, Endomycopsis scolyti, Candida tenuis, *and* C. rugosa *found in phloem only; and* C. silvicola *and* C. curvata, *associated with the beetle in California.*

62. Farris, S. H. 1965. REPOSITORIES OF SYMBIOTIC FUNGUS IN AMBROSIA BEETLE *MONARTHRUM SCUTELLARE* LEC. (COLEOPTERA: SCOLYTIDAE). Proc. Entomol. Soc. B.C. 62: 30–33.
Adult females transport symbiotic fungi in mycangia, which are enlargement of the forecoxal cavities similar to those described by Batra (1963) for other members of the genus. Male beetles do not have these structures.

63. Farris, S. H. 1965. A PRELIMINARY STUDY OF MYCANGIA IN THE BARK BEETLES, *DENDROCTONUS PONDEROSAE* HOPK., *DENDROCTONUS OBESUS* MANN., AND *DENDROCTONUS PSEUDOTSUGAE* HOPK. Can. Dep. For. Bimon. Prog. Rep. 21(5): 3–4.
Notes fungoid material at various locations on the body of adults, usually in the teneral stage. Mycangia had no associated gland cells or mucus secretions.

64. Farris, S. H. 1969. OCCURRENCE OF MYCANGIA IN THE BARK BEETLE *DRYOCOETES CONFUSUS* (COLEOPTERA: SCOLYTIDAE). Can. Entomol. 101: 527–532.
First record of mycangia in the genus Dryocoetes. *Both sexes contained paired oral pouches between the base of the mandibles and the ventral tentorial arm. Staining showed fungoid material in pouches but no associated gland cells. A related species,* D. affaber, *showed no fungal pouches. The pres-*

ence of mycangia in both sexes ensures inoculation of feeding tunnel and egg galleries.

65. Faulds, W. 1973. DISCOLOURATION ASSOCIATED WITH *PLATYPUS* WOUNDS IN LIVING *NOTHOFAGUS FUSCA*. N. Z. J. For. Sci. 3: 331–341.
*Staining may be a tree response to toxic substances produced by the microorganisms. Two fungi from insect tunnels in red beech (*Ceratocystis *sp. and* Endomycopsis platypodis*) and a nonsporulating fungus isolated from nearby tunnels, caused stains when inoculated into drilled holes resembling insect attack. Length of stains varied with microorganisms.*

66. Findlay, W. P. K. 1959. SAP-STAIN OF TIMBER. For. Abstr. 20: 1–7.
Mentions sapwood staining fungi not included in Francke-Grosmann's 1967 review. Fungi are often associated with bark beetle attacks. Discusses mode of infection and development of stain. Ceratocystis *species are the most important causes.*

67. Finnegan, R. J. 1967. NOTES ON THE BIOLOGY OF THE PITTED AMBROSIA BEETLE, *CORTHYLUS PUNCTATISSIMUS* (COLEOPTERA: SCOLYTIDAE), IN ONTARIO AND QUEBEC. Can. Entomol. 99: 49–54.
The male cuts the gallery and egg cradle and deposits spores of ambrosia fungi from specialized repositories in its thorax; the females lay eggs in a fungus mat and plugs the entrance with ambrosia mycelium.

68. Francke-Grosmann, H. 1966. ÜBER SYMBIOSEN VON XYLO-MYCETOPHAGEN UND PHLOEOPHAGEN SCOLYTOIDEA MIT HOLZBEWOHNENDEN PILZEN. [ON THE SYMBIOSIS OF XYLO-MYCETOPHAGOUS AND PHLOEOPHAGOUS SCOLYTOIDEA WITH WOOD-INHABITING FUNGI.] Holz und Org. Int. Symp. Berlin-Dahlem (1965) 1: 503–522.
Labels as "phloeomycetophagous" some bark-inhabiting beetles that have mycetangia (same as mycangia of Batra 1963) and feed as larvae on phloem colonized by specific fungal associates. Ten species of bark-breeding beetles had mycetangia that contained fungi: Ips acuminatus, Dendroctonus frontalis, D. brevicomis, D. mexicanus, D. parallelocollis, D. adjunctus, Myelophilus minor, Hylurgops palliatus, Hylastes ater, *and* H. cunicularius. *Proposes* Ceratocystis minor *as the main fungus of the* frontalis *and* brevicomis *mycetangia, but no cultures were made. Fungal flora are useful as food for juvenile beetles.*

69. Francke-Grosmann, H. 1967. ECTOSYMBIOSIS IN WOOD INHABITING INSECTS. Pages 142-205 *in* Symbiosis vol. 2, Edited by S. M. Henry. Academic Press, New York.
A comprehensive review (277 citations). Includes review of fungal transmission organs (mycangia) and covers four groups of insects: ambrosia beetles (xylomycetophagous Scolytoidea), bark-feeding bark beetles (some phloeophagous Scolytidae), ship timberworms (Lymexylidae), and wood wasps (Siricidae and Xiphydriidae).

70. Franklin, R. T. 1970. OBSERVATIONS ON THE BLUE STAIN-SOUTHERN PINE BEETLE RELATIONSHIP. J. Ga. Entomol. Soc. 5: 53–57.
Relationship between blue-stain fungi and southern pine beetle is not beneficial to beetles reared in a laboratory. Larvae made elongate mines and did not grow in the blue-stained inner bark. Parent beetles avoided stained areas when possible, though oviposition did not appear affected. Of over 190 egg niches, only 42 larvae matured and transformed into beetles. Fungi may reduce nutritive value of inner bark and may even be toxic or repellent to larvae and repellent to adults.

71. French, J. R. J., and R. A. Roeper. 1972. OBSERVATIONS ON *TRYPODENDRON RUFITARSIS* (COLEOPTERA: SCOLYTIDAE) AND ITS PRIMARY SYMBIOTIC FUNGUS, *AMBROSIELLA FERRUGINEA*. Ann. Entomol. Soc. Am. 65: 282.
*Reports the first isolation of the fungus from the beetle and describes a hibernating site of the insect—within a basidiomycete sporophore. Blue stain (*Ceratocystis *sp.) was observed in the three attacked trees but was not evident in the basal 4 feet of boles with galleries. Mycangia appeared identical in structure and size to those of* T. lineatum.

72. French, J. R. J., and R. A. Roeper. 1972. INTERACTIONS OF THE AMBROSIA BEETLE, *XYLEBORUS DISPAR* (COLEOPTERA: SCOLYTIDAE), WITH ITS SYMBIOTIC FUNGUS *AMBROSIELLA HARTIGII* (FUNGI IMPERFECTI). Can. Entomol. 104: 1635–1641.
Two biassays of various insect stages demonstrated the pleomorphic nature of the fungus and the importance of the ambrosial form for the growth and development of postdiapause adults and larvae. In culture, postdiapause adults and pupae cause a change from the mycelial to the ambrosial form. Without the ambrosial form, oviposition and pupation did not occur. The ambrosial form may be induced by a secretory product of the insect.

73. French, J. R. J., and R. A. Roeper. 1972. *IN VITRO* CULTURE OF THE AMBROSIA BEETLE *XYLEBORUS DISPAR* (COLEOPTERA: SCOLYTIDAE) WITH ITS SYMBIOTIC FUNGUS, *AMBROSIELLA HARTIGII*. Ann. Entomol. Soc. Am. 65: 719–721.
The first recorded rearing of a temperate zone scolytid on a fungus of the genus Ambrosiella. *Prediapause beetles failed to oviposit. Postdiapause adults produced a single generation when reared* in vitro *with its symbiotic fungus* Ambrosiella hartigii.

74. French, J. R. J., and R. A. Roeper. 1973. PATTERNS OF NITROGEN UTILIZATION BETWEEN THE AMBROSIA BEETLE *XYLEBORUS DISPAR* AND ITS SYMBIOTIC FUNGUS. J. Insect Physiol. 19: 593–605.
Uric acid was the main nitrogenous product found in excreta and hindguts of beetles, larvae, and pupae (range 7·6-14·8 μg uric acid per beetle). No ninhydrin-positive compounds were found in excreta. Concentration of ammonia-nitrogen in the various life stages averaged between 0·70 and 1·13

μg NH_3-N per beetle. Comparative concentrations of soluble proteins and free amino acids suggested that the fungus in the mycangia was formed from free amino acids of the insects. During the period of emergence, flight, and attack of new hosts, females had more than double the concentration of soluble proteins found the rest of the year. Free amino acids had the lowest values recorded during this period (March-October).

5. Frye, R. H., and N. D. Wygant. 1971. SPRUCE BEETLE MORTALITY IN CACODYLIC ACID-TREATED ENGELMANN SPRUCE TRAP TREES. J. Econ. Entomol. 64: 911–916.
The treatment was fatal to Dendroctonus rufipennis *and prevented brood development. Blue stain development was very light in treated trees and heavy in untreated ones.*

6. Funk, A. 1965. THE SYMBIOTIC FUNGI OF CERTAIN AMBROSIA BEETLES IN BRITISH COLUMBIA. Can. J. Bot. 43: 929–932.
Monilia ferruginea, M. brunnea, *and* Tuberculariella ambrosiae *n. sp. are the symbiotic fungi of* Trypodendron lineatum, Monarthrum scultellare, *and* Platypus wilsoni, *respectively. Isolations were from mycangia of beetles and from insect galleries.*

7. Funk, A. 1970. FUNGAL SYMBIONTS OF THE AMBROSIA BEETLE *GNATHOTRICHUS SULCATUS*. Can. J. Bot. 48: 1445–1448.
Describes three species of fungi originally found in beetle mycangia and tunnels in Douglas-fir from British Columbia: Ambrosiella sulcati *sp. nov.,* Raffaelea sulcati *sp. nov., and* Graphium *sp. Yeasts were always present but were not identified.*

8. Furniss, M. M., and P. W. Orr. 1970. DOUGLAS-FIR BEETLE. U. S. Dep. Agric. For. Pest Leafl. 5 (rev.), 4 p.
Death results from girdling effect of egg galleries and larval mines. Beetles introduce various fungi, which hasten death by clogging the sap-conducting system.

9. Giese, R. L. 1966. THE BIOECOLOGY OF *CORTHYLUS COLUMBIANUS* HOPKINS. Holz und Org. Int. Symp. Berlin-Dahlem (1965) 1: 361–370.
*Ten microorganisms were isolated from galleries over a 4 year period. Male beetles have a prothoracic mycangium that stores and transmits a new yeast (*Pichia *sp.), which assumes complete dominance in egg cradles and provides the entire nutrient mass for the larval stages. The yeast is the only organism that can be isolated from the egg chamber.* Ceratocystis *sp. becomes evident in the egg chamber following completion of the pupal stage.*

0. Giese, R. L. 1967. THE COLUMBIAN TIMBER BEETLE, *CORTHYLUS COLUMBIANUS* (COLEOPTERA: SCOLYTIDAE). V. A DESCRIPTION OF THE MYCETANGIA. Can. Entomol. 99: 54–58.
These structures lie immediately below the integument of the pronotum, one in each ventrolateral region. Each mycetangium (= mycangium) is a coiled tube that is 4.69 ± 0.35 mm in length, that is cream-colored, and that opens into the anterior coxal cavity. Mycetangia occur only in males and provide the overwintering storage site and transmission mechanism for associated microorganisms. Smears and cultures of the mycetangia were positive for ascospores and vegetative cells of the yeast Pichia *sp., which coincides with the microsymbiote dominant in developmental chambers of the larvae.*

81. Gouger, R. J. 1972. INTERRELATIONS OF *IPS AVULSUS* (EICHH.) AND ASSOCIATED FUNGI. Diss. Abstr. 32: 6453–B.
No mycangium was detected in the insect. Transmission of associated fungi may be accomplished by spores and yeast cells that either adhere to the exoskeleton or pass through the intestinal tract. Ectosymbiotic fungi consistently associated in winter and spring were Ceratocystis ips *and two yeasts—*Hansenula holstii *and* Pichia pini. *One or both yeasts or their associated bacteria may cause wild broods to be larger and to develop more rapidly than aseptic broods reared with or without* C. ips.

82. Graham, K. 1967. FUNGAL-INSECT MUTUALISM IN TREES AND TIMBER. Ann. Rev. Entomol. 12: 105–126.
Discusses various insect and fungoid mutualists and new aspects of isolating and culturing symbiotes. "Mutualism" implies an advantageous association between individuals of different species and precludes mere coexistence, competition, or benefit to only one associate. The genus Ceratocystis *occurs widely with both phloem-eating and wood-boring (ambrosial) species. Suggests need for information to determine if blue-stain fungi render the phloem more suitable as a habitat or as a food medium for bark beetles.*

83. Griffin, H. D. 1968. THE GENUS *CERATOCYSTIS* IN ONTARIO. Can. J. Bot. 46: 689–718.
A key to 60 species based mainly on ascospore characteristics. The bark beetles Ips pini *and* Orthotomicus caelatus *may be the principal vectors for several species including* Ceratocystis ips *and* C. minor.

84. Guerrero, R. T. 1966. UNA NEUVA ESPECIE DE HONGO IMPERFECTO ASOCIADO CON EL COLEÓPTERO *PLATYPUS SULCATUS* CHAPUIS. [NEW IMPERFECT FUNGUS ASSOCIATED WITH THE COLEOPTERA *PLATYPUS SULCATUS* CHAPUIS.] Patol. Veg. 3: 97–103.
Describes a new fungus Raffaelea santoroi *associated with* Platypus sulcatus. *Samples were from Argentina. Fungus was obtained by rasping gallery walls in* Eucalyptus camaldulensis *and* Laurus nobilis; *also found in expelled larval sawdust particles of* Quercus robur.

85. Happ, G. M., C. M. Happ, and S. J. Barras. 1971. FINE STRUCTURE OF THE PROTHORACIC MYCANGIUM, A CHAMBER FOR THE CULTURE OF SYMBIOTIC FUNGI, IN THE SOUTHERN PINE BEETLE, *DENDROCTONUS FRONTALIS*. Tissue and Cell 3: 295–308.
Fungi are cultured and transported to new host trees within a mycangium consisting of a cuticular invagination along the endothoracic fold. Two types of gland cells secrete into the mycangial lumen: one may provide the basic nutrient medium, and

the other may inhibit weed fungi and favor the growth of the symbiotic crop.

86. Hare, R. C. 1969. EFFECTS OF *CERATOCYSTIS MINOR* (HEDGC.) HUNT, THE BLUE-STAIN FUNGUS CARRIED BY *DENDROCTONUS FRONTALIS* ZIMM. ON BEETLE-RESISTANT AND -SUSCEPTIBLE PINE SPECIES. Final Rep. FS-SO-1401-5.18. U.S. Dep. Agric. For. Serv. South. For. Exp. Stn. Gulfport, Miss. 11 p.
Six year old shortleaf, loblolly, and slash pines were inoculated with pure cultures of C. minor *to determine if resistance to the beetle is correlated with resistance to the fungus. None of the trees died. Five months later,* C. minor *was reisolated 1 foot above the inoculated area.* C. minor *is not the primary cause of death in beetle-infested trees.*

87. Harrar, J. G., and R. P. Ellis. 1940. THE BIOLOGY OF A SPECIES OF *BEAUVERIA* FROM THE SOUTHERN PINE BARK BEETLE (ABSTR.). Proc. Va. Acad. Sci. 1: 211.
This unidentified Beauveria *was isolated from larvae and was found to be pathogenic to healthy larvae. Growth characteristics, reproductive structures, and nutritional requirements were studied to evaluate its potential as a biological control agent. No data were presented.*

88. Harrar, J. G., and J. G. Martland. 1940. THE ETIOLOGY OF THE *BEAUVERIA* DISEASE OF *DENDROCTONUS FRONTALIS* (ABSTR.). Proc. Va. Acad. Sci. 1: 211.
Isolates of Beauveria *sp. from the southern pine beetle were used in histological studies of infection in larvae. Reports mode of infection, action within the host, and methods of fructification.*

89. Harrar, J. G., and J. G. Martland. 1940. A FUNGOUS PARASITE OF THE PINE BARK BEETLE (ABSTR.). Phytopathology 30: 8.
Many dead or dying larvae in shortleaf pines from eastern Virginia were found infested with both fungi and nematodes. Monosporous cultures showed that the fungus was probably a Beauveria.

90. Hedgecock, G. G. 1906. STUDIES UPON SOME CHROMOGENIC FUNGI WHICH DISCOLOR WOOD. Rep. Mo. Bot. Gard. 17: 59–114.
Gives keys and descriptions of several Ceratostomella *spp. (=* Ceratocystis*),* Graphium *spp., and other wood staining fungi. The presence of blue staining fungi in the tunnels of some wood boring beetles indicates that the insects carry conidia or ascospores.*

91. Heller, R. C. 1968. PREVISUAL DETECTION OF PONDEROSA PINE TREES DYING FROM BARK BEETLE ATTACK. Pages 387-434 *in* Proc. 5th Symp. on Remote Sensing of Environment. Univ. Mich., Ann Arbor.
Aerial sensors have not been successful in detecting attacked trees before discoloration, and ground observations are inadequate for appraising the success of an attack. The best method of evaluation is to examine the xylem for the blue stain fungus Ceratostomella *spp. (=* Ceratocystis *spp.). Color transparencies revealed three times as many dying trees as ground observations.*

92. Helms, J. A., F. W. Cobb, Jr., and H. S. Whitney. 1971. EFFECT OF INFECTION BY *VERTICICLADIELLA WAGENERII* ON THE PHYSIOLOGY OF *PINUS PONDEROSA*. Phytopathology 61: 920–925.
Discussion of the fungus with emphasis on its tendency to predispose trees to bark beetle attack. Fungus-infested pines > 20 cm d.b.h. usually die from root disease following attacks by Dendroctonus brevicomis *or* D. ponderosa. *Although seedlings showed no visual symptoms 1 month after inoculation with the fungus, dramatic decreases in net photosynthesis and transpiration occurred along with marked increases in foliar water stress and stomata closure.*

93. Himes, W. E., and J. M. Skelly. 1972. AN ASSOCIATION OF THE BLACK TURPENTINE BEETLE *DENDROCTONUS TEREBRANS*, AND *FOMES ANNOSUS* IN LOBLOLLY PINE (ABSTR.). Phytopathology 62: 670.
A total of 1,438 insects in various stages of development were removed from roots and lower boles of infested trees and were incubated at 23°C for 14 days on pine discs. The fungus was isolated from 11.5 percent of these insects. The Oedocephalum *form of the fungus was found in 9 of 130 larval galleries. None of the 13 canals produced by adults was positive. The insect is a likely vector.*

94. Hinds, T. E., and P. E. Buffam. 1971. BLUE STAIN IN ENGELMANN SPRUCE TRAP TREES TREATED WITH CACODYLIC ACID. U.S. Dep. Agric. For. Serv. Res. Note RM-201, 4 p. Rocky Mt. For. Exp. Stn., Fort Collins, Colo.
One year after treatment blue stain development was negligible and bark beetle development poor in trap trees treated 4-8 weeks and felled 2-4 weeks before peak flight. Leptographium engelmannii *was isolated from 95 percent of the blue stain samples.* Ceratocystis olivacea, C. coerulescens, C. *sp. and* Graphium *spp. were less consistent.* C. coerulescens *was isolated from 80 percent of the brown stain samples associated with ambrosia beetles. Incipient decay in stain areas of felled trees was evident and was caused by the sap rot fungus* Fomes pinicola *and two unidentified sp.*

95. Hinds, T. E., and R. W. Davidson. 1972. *CERATOCYSTIS* SPECIES ASSOCIATED WITH THE ASPEN AMBROSIA BEETLE. Mycologia 64: 405–409.
Describes a new species Ceratocystis retusi, *which has brown perithecia and long, flexuous ostiolar filaments. This species and* C. brevicollis *were commonly found in Colorado in pupal cells of the aspen ambrosia beetle* Trypodendron retusum.

96. Hodges, J. D., S. J. Barras, and J. K. Mauldin. 1968. AMINO ACIDS IN INNER BARK OF LOBLOLLY PINE, AS AFFECTED BY THE SOUTHERN PINE BEETLE AND ASSOCIATED MICROORGANISMS. Can. J. Bot. 46: 1467–1472.
Bolts infected with an ascomycete (Ceratocystis minor), *with a basidiomycete mycangial fungus (SJB 122), or with the beetle-microorganism complex brought about no qualitative changes in free*

amino acids but produced changes in protein-bound ones. Concentration of most free amino acids and soluble nitrogen decreased, but that of most protein-bound amino acids, insoluble nitrogen, and total nitrogen increased.

Holst, E. C. 1936. *ZYGOSACCHAROMYCES PINI*, A NEW SPECIES OF YEAST ASSOCIATED WITH BARK BEETLES IN PINES. J. Agric. Res. 53: 513–518.
Describes and reports distribution of a new yeast (Pichia pini) *isolated from specimens and galleries of* Dendroctonus brevicomis *and* D. frontalis *and also associated with* Ips grandicollis, I. avulsus, *and* I. calligraphus.

Holt, W. R. 1961. *METARRHIZIUM ANISOPLIAE* (METCHNIKOFF) SOROKIN INFECTING LARVAE OF THE BLACK TURPENTINE BEETLE. J. Insect Pathol. 3: 93–102.
Reports probable new host record for a fungus isolated from full grown larvae under the bark of a loblolly pine stump in southern Mississippi.

Hoog, G. S. de. 1974. THE GENERA *BLASTOBOTRYS, SPOROTHRIX, CALCARISPORIUM* AND *CALCARISPORIELLA* GEN. NOV. Studia Mycol. (Netherlands) 7: 1–84.
The genus Blastobotrys, comprising only one species, *is described. The genus* Sporothrix *is enlarged to include 24 species: six are new; three are new combinations; 13 are conidial states of* Ophiostoma; *one is excluded.* Calcarisporium *is restricted to one species.* Calcarisporiella *is described.* Ceratocystis, *an Ascomycete genus, is divided into two separate genera based on the morphology of the conidial states:* Ceratocystis sensu stricto *comprises species with* Chalara, Chalaropsis, *and* Thielaviopsis *conidial states; most species of* Ceratocystis auctt. *have* Sporothrix, Verticicladiella, *and* Graphium *states and are here classified in* Ophiostoma.

Hosking, G. P. 1972. *XYLEBORUS SAXESENI*, ITS LIFE HISTORY AND FLIGHT BEHAVIOR IN NEW ZEALAND. N. Z. J. For. Sci. 3: 37–53.
Rate of development is influenced mainly by ambrosia fungi (unidentified) and indirectly by climatic factors and physiological condition of the host.

Howe, V. K., A. D. Oberle, T. G. Keeth, and W. J. Gordon. 1971. THE ROLE OF MICROORGANISMS IN THE ATTRACTIVENESS OF LIGHTNING-STRUCK PINES TO SOUTHERN PINE BEETLES. West. Ill. Univ. Bull. 50(3), 44 p. Ser. Biol. Sci. 9.
Of 577 yeasts, fungi, and bacteria isolated from bark beetle galleries and exposed inner bark of struck loblolly pines (Pinus taeda), *214 yeasts and 207 hyphal fungi were identified to species, and 12 bacteria to genera. Olfactometer tests indicated that the microorganisms produced no volatile substances attractive to the insect.*

Islas, S. F. 1974. OBSERVACIONES SOBRE LA BIOLOGIA Y EL COMBATE DE LOS ESCARABAJOS DESCORTEZADORES DE LOS PINOS: *DENDROCTONUS ADJUNCTUS* BLF. Y *DENDROCTONUS MEXICANUS* HPK. EN ALGUNAS REGIONES DEL ESTADO DE MEXICO. [OBSERVATIONS ON THE BIOLOGY AND CONTROL OF PINE BARK BEETLES: *DENDROCTONUS ADJUNCTUS* BLF. AND *D. MEXICANUS* HPK. IN SOME REGIONS OF THE STATE OF MEXICO.] Bol. Tech. 40, 35 p. Inst. Nac. de Invest. For. Mexico City, D.F.
Various fungicides (especially modifications of the Bordeaux type) gave from 25 to 50 percent recovery if trees were treated during the first week of attack; little or no fungal growth was observed. Resistant trees produced yellowish-white resin pitch tubes. A "special substance" in the resin impedes the development of associated fungi. A biological control study with Metarrhizium anisopliae *was incomplete.*

103. Jouvenaz, D. P., and R. C. Wilkinson. 1970. INCIDENCE OF *SERRATIA MARCESCENS* IN WILD *IPS CALLIGRAPHUS* POPULATIONS IN FLORIDA. J. Invertebr. Pathol. 16: 295–296.
In laboratory cultures, chromogenic strains were consistently isolated from both live and dead I. calligraphus, *but mortality was less than 1 percent per generation. Mature larvae and pupae associated with teneral adults in loose old bark had a higher incidence of the bacteria than larvae and pupae associated with parent adults in tight fresh bark; teneral adults had a higher incidence of bacteria than parent adults.*

104. Kabir, A. K. M. F., and R. L. Giese. 1966. THE COLUMBIAN TIMBER BEETLE, *CORTHYLUS COLUMBIANUS* (COLEOPTERA: SCOLYTIDAE). II. FUNGI AND STAINING ASSOCIATED WITH THE BEETLE IN SOFT MAPLE. Ann. Entomol. Soc. Am. 59: 894–902.
Graphium *sp. near* rigidum, Ceratocystis pluriannulata, Fusarium tricinctum, F. oxysporum, F. solani, Pichia *n. sp.*, Gliocladium roseum, *and* Rhizoctonia *sp. were isolated from galleries of* Corthylus columbianus *and associated stains in* Acer saccharinum. *The white pseudomycelial mat of* Pichia *sp. is very conspicuous in egg chambers during egg and larval stages, and the larvae depend solely upon it for food. Optimum growth temperature was 65°-85°F for the* Ceratocystis *and 65°-75°F for the* Pichia. *Only* Ceratocystis *grew at 40° or 90°F. No stain developed in sapwood blocks inoculated in the laboratory.*

105. Kaneko, T. 1965. BIOLOGY OF SOME SCOLYTID AMBROSIA BEETLES ATTACKING TEA PLANTS. I. GROWTH AND DEVELOPMENT OF TWO SPECIES OF SCOLYTID BEETLES REARED ON STERILIZED TEA PLANTS. Jap. J. Appl. Entomol. Zool. 9: 211–216.
Xyleborus compactus *and* X. germanus *were successfully reared in test tubes. Steam-sterilized substrates were tea twigs for* X. compactus *and tea roots or twigs for* X. germanus. *Growth rate and size of maturing broods varied with fungal growth, which is determined by wood condition.*

106. Kaneko, T. 1967. SHOT-HOLE BORER OF TEA PLANT IN JAPAN. Jap. Agric. Res. Q. 2: 19–21.
The fungus associated with Xyleborus germanus *and* X. compactus *has two stages, the stored spore stage, which occurs in the mycangia, and the culti-*

vated spore stage, which occurs in the galleries. Virgin females with their associated ambrosia fungi produce haploid males; in the absence of fungi, no reproduction takes place.

107. Kaneko, T., and K. Takagi. 1965. BIOLOGY OF SOME SCOLYTID AMBROSIA BEETLES ATTACKING TEA PLANTS. IV. PARTHENOGENESIS OF *XYLEBORUS GERMANUS* BLAND. IN RELATION TO THE *GERMANUS* AMBROSIA FUNGUS. Jap. J. Appl. Entomol. Zool. 9: 303–304.
Beetle has a polygamous social organization with a sex ratio of about 10:1 (female to male). All adult females (mated and nonmated) provided with the ambrosia fungus reproduced. Noncopulated females produced only male progeny; mated females produced both female and male progeny.

108. Kaneko, T., and K. Takagi. 1966. BIOLOGY OF SOME SCOLYTID AMBROSIA BEETLES ATTACKING TEA PLANTS. VI. A COMPARATIVE STUDY OF TWO AMBROSIA FUNGI ASSOCIATED WITH *XYLEBORUS COMPACTUS* EICHHOFF AND *XYLEBORUS GERMANUS* BLANDFORD (COLEOPTERA: SCOLYTIDAE). Appl. Entomol. Zool. 1: 173–176.
Both the tea root borer X. germanus *and the tea twig borer* X. compactus *reproduced normally following artificial exchanges of their symbiotic ambrosia fungi. The fungi appeared morphologically and physiologically alike with the exception of different optimum temperatures of sporulation in cultivated spores.*

109. Kaneko, T., Y. Tamaki, and K. Takagi. 1965. PRELIMINARY REPORT ON THE BIOLOGY OF SOME SCOLYTID BEETLES, THE TEA ROOT BORER, *XYLEBORUS GERMANUS* BLANFORD, ATTACKING TEA ROOTS, AND THE TEA STEM BORER, *XYLEBORUS COMPACTUS* EICHHOFF, ATTACKING TEA TWIGS. Jap. J. Appl. Entomol. Zool. 9: 23–28.
The optimum temperature for mycelial growth of ambrosia fungi was 23°C for X. germanus *and 26°C for* X. compactus. X. germanus *was reared completely through one generation and partially through another on autoclaved wood colonized by the ambrosia fungus. When the fungus grew on agar-based media, the insect did not develop.*

110. Kimmey, J. W., and R. L. Furniss. 1943. DETERIORATION OF FIRE-KILLED DOUGLAS-FIR. U.S. Dep. Agric. Tech. Bull. 851, 61 p.
Most fungi causing wood stain belong to the genus Ceratostomella (= Ceratocystis). *The Douglas-fir beetle is a carrier of* Ceratostomella pseudotsugae (= Ceratocystis minor), *which influences the early stage of sapwood deterioration. The Douglas-fir beetle is the most important insect pest that attacks fire-killed timber. The beetle opens the bole to other agents of deterioration and may accelerate the establishment of fungi. Three species of ambrosia beetles,* Trypodendron bivittatum, Gnathotrichus retusus, *and* G. sulcatus, *cause degrade by making pinholes and by introducing blue-stain fungi.* Platypus wilsoni *occasionally causes pinholes but is not economically important.*

111. King, B., and H. O. W. Eggins. 1972. SOME OBSERVATIONS ON DECAY MECHANISMS OF MICROFUNGI DETERIORATING WOOD. Pages 145-151 *in* Biodeterioration of Materials, vol. 2. Edited by A. H. Walters and E. H. Hueck-van der Plas. John Wiley & Sons, New York.
Discusses 33 species of fungi, including many mold and blue stain, commonly associated with attacked green wood. Growth rate patterns correlated with utilization rates of starch and cellulose agar and with liquification of pectin gels. Ceratocystis pilifera, *which grew quickly and was highly amylolytic, cleared cellulose agar and liquified pectate gels.* C. coerulescens *grew more slowly, was less active, and showed maximum cellulolytic activity.* C. ulmi *and* C. picea *were slow growing and showed slight cellulolytic activity.*

112. Koch, A. 1963. ON THE ROLE OF THE SYMBIONTS IN WOOD-DESTROYING INSECTS. Recent Progress in Microbiol. 8: 151–161.
Discusses symbionts of various insect groups: Ipidae, Platypodidae, Lymexylonidae, Siricidae, Anobiidae, Cerambycidae, and Lyctidae. The symbionts provide or supplement necessary vitamins and proteins and participate in the nitrogen metabolism of their hosts, whose metabolic by-products are used by the symbionts.

113. Kok, L. T., D. M. Norris, and H-M Chu. 1970. STEROL METABOLISM AS A BASIS FOR A MUTUALISTIC SYMBIOSIS. Nature 225: 661–662.
Ergosterol was the only sterol produced by the mutualistic fungus Fusarium solani, *associated with the beetle* Xyleborus ferrugineus, *in pure culture on a chemically defined sterile substrate. Ergosterol was adequate for continued growth, development, and reproduction of the fungus-free beetle. The insect is apparently unique in its use of cholesterol for egg production and larval growth but not for pupation.*

114. Kotýnková-Sychrová, E. 1966. MYKOFLÓRA CHODEB KŮROVCŮ V ČESKOSLOVENSKU. [THE MYCOFLORA OF BARK-BEETLE GALLERIES IN CZECHOSLOVAKIA.] Česká Mykol. 20: 45–53.
Thirteen pathologically important species of fungi (11 Ceratocystis *species,* Leptographium lundbergii, *and* Graphium pycnocephalum) *were isolated from galleries of bark beetles of the genera* Ips, Hylurgops, Xyloterus, Pityogenes, Dryocoetes, *and* Myelophilus.

115. Kulman, H. M. 1964. PITCH DEFECTS IN RED PINE ASSOCIATED WITH UNSUCCESSFUL ATTACKS BY *IPS* SPP. J. For. 62: 322–325.
Unsuccessful attacks produced vertical bark scars and catfaces on red pine in Virginia and West Virginia. The scars lay directly over wood surface depressions, which were above pitch defects buried under one to eight annual growth rings. The defects were composed of Ips *nuptial chambers and egg galleries. The failure of some attacks may be explained by an absence of blue stain in the wounds.*

116. Le Fay, A., J. E. Courtois, A. Thuillier, C. Chararas, and S. Lambin. 1969. ÉTUDE DES OSIDASES

DE L'INSECTE XYLOPHAGE *IPS SEXDENTATUS* ET DE SA FLORE MICROBIENNE. [THE STUDY OF THE OXIDASES OF THE XYLOPHAGOUS INSECT *IPS SEXDENTATUS* AND ITS MICROBIAL FLORA.] C. R. Acad. Sci. 268: 2968–2970.
Extracellular microbes in the digestive tract of the insect are Achromobacter superficialis, A. delicatulus, *and* Candida pulcherina. *The microbial flora contain several oxidases. The insect possessed various enzymes that enabled it to degrade numerous oligosaccharides and polysaccharides. The activity of these enzymes is less important and less varied in the microbes than in the insect.*

7. Le Fay, A., J. E. Courtois, A. Thuillier, C. Chararas, and S. Lambin. 1970. ÉTUDE DES OSIDASES DE L'INSECTE XYLOPHAGE *IPS SEXDENTATUS* ET DE SA FLORE MICROBIENNE. I. ÉTUDE DE LA FLORE MICROBIENNE ET COMPARISON DE SES OSIDASES AVEC CELLES DE L'INSECTE TOTAL. [STUDY OF THE OXIDASES OF THE XYLOPHAGOUS INSECT *IPS SEXDENTATUS* AND OF ITS MICROBIAL FLORA. I. STUDY OF THE MICROBIAL FLORA AND COMPARISON OF THEIR OXIDASES WITH CELLS OF THE WHOLE INSECT.] Ann. Inst. Pasteur 119: 483–491.
*Two bacteria (*Achromobacter *spp.) and one yeast (*Candida *spp.) isolated regularly from the alimentary canal of* I. sexdentatus *had various enzymes that were less important and diversified than those of the insect at all developmental stages. Enzymes included glucosidases, galactosidase, amylase, pectinase, and cellulase.*

8. Le Fay, A., A. Thuillier, C. Chararas, and J. E. Courtois. 1969. INFLUENCE DE LA DESTRUCTION SÉLECTIVE DE LA FLORE MICROBIENNE SUR L'ACTIVITÉ DE DEUX OSIDASES CHEZ L'INSECTE XYLOPHAGE *IPS SEXDENTATUS*. [INFLUENCE OF THE SELECTIVE DESTRUCTION OF THE MICROBIAL FLORA ON THE ACTIVITY OF TWO OXIDASES ON THE XYLOPHAGOUS *IPS SEXDENTATUS*.] C. R. Acad. Sci. 268: 3130–3132.
In adults reared on wood impregnated with antibacterial and antifungal substances, two bacteria and a yeast in the digestive tube of the insect were selectively destroyed by inhibitory substances. No significant modification of the enzymatic activity of pectin and hydroxyethyl cellulose occurred in insects with ingested antibiotics, antibacterial agents, or antifungal agents. The microbial flora apparently function as accessories in elaborating the two oxidases in the total enzymatic complex.

9. Le Fay, A., A. Thuillier, J. E. Courtois, and C. Chararas. 1970. ÉTUDE DES OSIDASES DE L'INSECTE XYLOPHAGE *IPS SEXDENTATUS* ET DE SA FLORE MICROBIENNE. II. INFLUENCE DE LA DESTRUCTION SÉLECTIVE DE LA FLORE MICROBIENNE SUR L'ACTIVITÉ DE PECTINASES ET DE CELLULASES ACTIVES EN MILIEU FAIBLEMENT ACIDE CHEZ UN INSECTE XYLOPHAGE. [STUDY OF THE OXIDASES OF THE XYLOPHAGOUS INSECT *IPS SEXDENTATUS* AND OF ITS MICROBIAL FLORA. II. INFLUENCE OF THE SELECTIVE DESTRUCTION OF THE MICROBIAL FLORA ON THE ACTIVITY OF PECTINASES AND CELLULASES ACTIVE IN A WEAKLY ACID MEDIUM WITHIN A XYLOPHAGOUS INSECT.] Ann. Inst. Pasteur 119: 745–751.
Beetles were reared on Scots pine logs treated with antibiotics to selectively kill Achromobacter superficialis, A. delicatulus *and* Candida pulcherina *symbionts in insect digestive tracts. No significant change in enzymatic activity was noted with pectin and hydroxyethyl cellulose as substrates; thus, the symbionts are of little importance in providing enzymes.*

120. Lekander, B., and E. Rennerfelt. 1955. UNDERSÖKNINGAR ÖVER INSEKTS-OCH BLÅNADSSKADOR PA SAGTIMMER. [INVESTIGATIONS OF DAMAGE CAUSED BY BARK BEETLES AND BLUEING FUNGI IN SAW TIMBER.] Medd. Statens Skogsforskningsinstitut. 45(8): 1–36.
Surveys the most important blueing fungi [including Cladosporium, Pullularia, *and* Ophiostoma (= Ceratocystis)*] spread either by air or by forest insects; also discusses the most damaging insects that transmit stain in Sweden. Insects are* Blastophagus minor *and* Ips acuminatus *on Scots pine,* I. typographus *on Norway spruce, and* Trypodendron lineatum *on pine and spruce.*

121. Liese, W. 1970. ULTRASTRUCTURAL ASPECTS OF WOODY TISSUE DISINTEGRATION. Ann. Rev. Phytopathol. 8: 231–258.
Pullularia pullans *and* Ophiostoma (= Ceratocystis) coeruleum *are discussed. Passive penetration of the cell wall by blue stain fungi is by means of a transpressorium. Coaction of mechanical forces and enzymes produced at the tip of the transpressorium probably occurs. Further widening of the canals did not occur nor were there any visible changes in cell wall structure. The blue stain fungi derive nutrients from parenchyma cells.*

122. Liese, W. 1971. THE ACTION OF FUNGI AND BACTERIA DURING WOOD DETERIORATION. Int. Pest Control 1: 20–24.
Some blue stain fungi causing sapwood discoloration grew inside ray cells and derived nutrients from parenchyma cells. Since no enzymes are produced that can degrade a cell wall, the fungus enters by mechanical pressure. Bacteria are found in parenchyma cells of sapwood, whose contents provide easily accessible nutrition; the bacteria generally have a lower and more restrictive lytic activity than fungi, and cell wall deterioration is therefore prolonged.

123. Livingston, R. L. 1971. ASPECTS OF THE RELATIONSHIP BETWEEN THE FIR ENGRAVER *SCOLYTUS VENTRALIS* (COLEOPTERA: SCOLYTIDAE) AND CERTAIN ASSOCIATED FUNGI. Ph.D. Thesis. Wash. State Univ. (Diss. Abstr. 32: 2777B.)
Trichosporium symbioticum *has been isolated from*

phloem, larval mines, internally from larvae, and externally from pupae, and from both parent and emerging adults. An unidentified yeast was found associated with larvae and adult beetles. Both fungi were consistently found together. Specialized organs (mycangia) for transport of fungi were located in the head of male and female beetles. Observations on the benefit of the fungus to the beetle proved inconclusive.

124. Livingston, R. L., and A. A. Berryman. 1972. FUNGUS TRANSPORT STRUCTURES IN THE FIR ENGRAVER, *SCOLYTUS VENTRALIS* (COLEOPTERA: SCOLYTIDAE). Can. Entomol. 104: 1793–1800.
Beetles were examined by serial paraffin sections and scanning electron microscopy. In both male and female adult beetles, small cup-shaped pits covering the top and portions of the side of the head consistently contained fungal spores and usually contained a wax-like material in which the spores were imbedded. This material was probably produced by secretory cells of the epidermis.

125. Lowe, R. E., R. L. Giese, and M. L. McManus. 1967. MYCETANGIA OF THE AMBROSIA BEETLE *MONARTHRUM FASCIATUM*. J. Invertebr. Pathol. 9: 451–458.
Females contain paired, saclike mycetangia (= mycangium) that lie dorsal to the prothoracic coxal cavities. These large specialized organs for storage and transport of the ambrosia fungus spores are apparently lined with sclerotized cuticular material, and the posterior portion is heavily musculatured. A tube extends from each mycetangium to an external opening in the procoxal cavity. One section of the organ wall adjacent to the tube lacks sclerotization and contains a series of cells and ducts that terminate in pores within the mycetangia. These may be secretory cells that provide the matrix surrounding the spore aggregates.

126. Lu, K. C., D. G. Allen, and W. B. Bollen. 1957. ASSOCIATION OF YEASTS WITH THE DOUGLAS-FIR BEETLE. For. Sci. 3: 336–343.
Isolations were made from galleries, exoskeletons, and alimentary tracts. The species isolated—either alone or mixed—were: Saccharomyces pastoria, Candida parapsilosis, C. mycoderma, *and* Hansenula capsulata. *Together, the four species were attractive to the beetle; separately,* S. pastoria *was significantly attractive,* H. capsulata *gave inconclusive results, and the other two species were rejected by the beetle.*

127. MacCallum, B. D. 1922. SOME WOOD-STAINING FUNGI. Trans. Brit. Mycol. Soc. 7: 231–236.
Graphium penicillioides *was considered as a stage in the life-history of* Ceratostomella piceae (= Ceratocystis piceae). *The fungus was observed on* Pinus sylvestris *attacked by* Hylesinus piniperda.

128. MacLean, D. B., and R. L. Giese. 1967. THE LIFE HISTORY OF THE AMBROSIA BEETLE *XYLOTERINUS POLITUS* (COLEOPTERA: SCOLYTIDAE). Can. Entomol. 99: 285–299.
Callow adults first reverse their position in the egg cradles, then begin feeding on an ambrosial fungus that lines the walls of the cradle and is as yet unidentified. The fungus was found consistently in active larval cradles and is probably the main larval food source.

129. MacLean, D. B., and R. L. Giese. 1968. FUNGI ASSOCIATED WITH *XYLOTERINUS POLITUS* (SAY) (COLEOPTERA: SCOLYTIDAE). J. Invertebr. Pathol. 10: 185–189.
Aspergillus flavus *was isolated from overwintering adult females of* Xyloterinus politus *along with* Penicillium *sp.,* Fusarium *sp., and an unidentified bacteria.* A. flavus *isolates from the prothorax were probably from the mycetangia. An unknown fungus, probably the main larval food source, was isolated and described from the cradles and galleries of actively feeding larvae. Pre-emergent adults feed on the fungus lining the old larval cradles; such behavior may cause the introduction of viable spores into the mycetangia.*

130. Mariat, F. 1971. ADAPTATION DE *CERATOCYSTIS* A LA VIE PARASITAIRE CHEZ L'ANIMAL-ETUDE DE L'AQUISITION D'UN POUVOIR PATHOGENE COMPARABLE A CELUI DE *SPOROTHRIX SCHENCKII*. [ADAPTATION OF *CERATOCYSTIS* TO PARASITIC LIFE IN THE ANIMAL - STUDY OF THE ACQUISITION OF ITS PATHOGENIC ABILITY AS COMPARED TO THAT OF *SPOROTHRIX SCHENCKII*.] Sabouraudia 9: 191–205.
Ceratocystis stenoceras, *usually parasitic on plants, was pathogenic for the hamster and mouse. Unicellular forms grown at 35° C produced lesions in some animals. Passaged strains were always more virulent than wild ones, did not form perithecia, and are considered to be stable, asexual pathogenic mutants. They produced triangular, pigmented spores and are indistinguishable from* S. schenckii *in morphology, physiology, and pathogenicity. The experimentally produced disease was similar to experimental sporotrichosis. The presence of cigar-shaped and asteroid bodies suggests that* Ceratocystis *may cause spontaneous sporotrichosis.*

131. Mason, R. R. 1967. DYNAMICS OF *IPS* POPULATIONS AFTER SUMMER THINNING IN A LOBLOLLY PINE PLANTATION: WITH SPECIAL REFERENCE TO HOST TREE RESISTANCE. Ph.D. Thesis. Univ. of Mich. 152 p. (Diss. Abstr. 27: 2215–B.)
Reasserts that the blue stain fungus Ceratocystis ips *is invariably found within the galleries and chambers of* Ips avulsus *and* Ips grandicollis. *The exact nature of the relationship between the fungus and the beetle remains unclear.*

132. Mathre, D. E. 1964. EFFECT OF *CERATOCYSTIS IPS* AND *CERATOCYSTIS MINOR* ON THE FREE SUGAR POOL IN PONDEROSA PINE SAPWOOD. Contrib. Boyce Thompson Inst. 22: 509–511.
Free sugars are most prevalent in the ray parenchyma cells, where fungal hyphae are most abundant. Fructose was apparently utilized by both fungi since it was abundant in uninfected sapwood but was not present in infected wood. Large quantities of xylose appeared in wood infected with C. minor, *but very little was found in wood in-*

fected with C. ips *or in noninfected wood. Hemicellulolytic enzyme activity may account for the presence of xylose. The presence of detectible galacturonic acid and mannitol suggests that pectolytic and dehydrogenase activity may also occur.*

3. Mathre, D. E. 1964. PATHOGENICITY OF *CERATOCYSTIS IPS* AND *CERATOCYSTIS MINOR* TO *PINUS PONDEROSA*. Contrib. Boyce Thompson Inst. 22: 363–388.

The fungi were pathogenic to small (<9 cm d.b.h.) ponderosa pines. Death resulted more quickly (<20 days) when inoculation covered 40-cm bands of sapwood rather than 10- or 20-cm bands. Trees inoculated in small patches and needle holes to simulate beetle attacks usually showed resistance to infection, probably because of copius resin flow. Dye studies showed that water is conducted around but not through infected areas of sapwood. Pathogenicity may involve entry of air into the sapwood.

4. Mathre, D. E. 1964. SURVEY OF *CERATOCYSTIS* SPP. ASSOCIATED WITH BARK BEETLES IN CALIFORNIA. Contrib. Boyce Thompson Inst. 22: 353–362.

Ceratocystis minor *was isolated from old galleries of* Dendroctonus brevicomis *and* D. monticolae; C. ips *was isolated from galleries and adults of* D. valens, Ips confusus, *and* I. oregonis, *and from galleries only of* D. monticolae, I. ponderosae, *and* I. emarginatus; C. schrenkiana *was associated with attacks of* D. valens *and* D. monticolae; C. montia, *with* D. jeffreyi *and* D. monticolae; *and* C. minuta, *with* I. confusus *and* I. emarginatus. *Inoculations of the sapwood of small (<9 cm d.b.h.) ponderosa pine with* C. ips, C. minuta, *and* C. schrenkiana *killed the trees after various periods of time.*

5. Mathre, D. E. 1964. STUDIES ON THE PATHOGENICITY TO PONDEROSA PINE OF *CERATOCYSTIS* SPP. ASSOCIATED WITH BARK BEETLES IN CALIFORNIA. Ph.D. Thesis. Univ. of Calif., Davis. 61 p. (Diss. Abstr. 27: 349B.)

The pathogenicity of some blue-stain fungi was tested to determine the role of these fungi in the death of beetle-attacked trees. Trees successfully attacked by bark beetles usually die within a few weeks to several months. The exact cause of death has not been fully established. Since mechanically girdled trees will live 1 or more years, the girdling action of the beetles does not explain the rapid death of the tree. The almost constant association of blue-staining fungi with bark beetles suggests that these fungi may be a cause of tree death.

6. McCambridge, W. F. 1974. IDENTIFYING PONDEROSA PINES INFESTED WITH MOUNTAIN PINE BEETLES. U.S. Dep. Agric. For. Serv. Res. Note RM-273, 2 p. Rocky Mt. For. and Range Exp. Stn., Ft. Collins, Colo.

Describes characteristics of successfully attacked trees. Blue stain infection of wood under the bark is indicated by a dull blue color. A long, narrow strip of infection is usually not fatal, but infection well distributed around the tree and accompanied by fine insect frass or brood indicates a fatal attack.

7. McCowan, J. C., and J. A. Rudinsky. 1958. BIOLOGICAL STUDIES ON THE DOUGLAS FIR BARK BEETLE. Weyerhaeuser Timber Co. For. Res. Note 11, 21 p. Millicoma Forest Tree Farm, Coos Bay, Oregon.

Many Dendroctonus *larvae die of starvation.* Ceratostomella pseudotsugae (= Ceratocystis minor) *and other fungi introduced by adult beetles cause decomposition of the cambium and render it unsuitable as larval food. A secondary enemy,* Dryocoetes pseudotsugae, *was abundant in windthrown trees infested with Douglas-fir beetles and particularly noticeable in trees with heavy blue stain and high larval mortality. The stain accompanies ambrosia beetles, which cause damage by constructing long winding tunnels into sapwood and heartwood.*

138. Meiffren, M., and M. Belin. 1960. ESSAI DE TRAITEMENT MIXTE INSECTICIDE ET FONGICIDE CONTRE LE SCOLYTE DES RAMEAUX DU CAFÉIER *XYLEBORUS MORSTATTI* HAGED. [TEST OF MIXED INSECTICIDE AND FUNGICIDE TREATMENT AGAINST THE SCOLYTID OF COFFEE BRANCHES *XYLEBORUS MORSTATTI* HAGED.] Rev. Café, Cacao. Thé. 4: 150–158.

When the insect bores into branches and excavates a gallery, a canker often forms on all sides of the entrance. Several hundred isolations revealed the following fungi in decreasing order of frequency: Colletotrichum coffeanum, Pestalozzia coffeicola, Botryodiplodia theobromae, Fusarium decemellulare, F. lateritium, Aspergillus *sp., and* Penicillium *sp.* C. coffeanum, *which with* P. coffeicola *is an agent of anthracnose, accounted for 80 percent of the isolations either alone or in associations with other species.*

139. Miller, D. L., and A. D. Partridge. 1974. ROOT ROT INDICATORS IN GRAND FIR. U.S. Dep. Agric. Plant Dis. Rep. 58: 275–276.

Roots of normal, discolored, and dying grand fir (Abies grandis) *were examined along with aboveground signs and symptoms as predictors of root rot, primarily* Armillaria mellea. *Bark beetle galleries or discolored foliage were the only effective indicators of the root rots. Of the root-rotted trees, 75.71 percent had new bark beetle galleries and 74.29 percent had yellow or red foliage. 98.15 percent of the bark beetle damage was in trees with advanced root decay.*

140. Miller, J. M., and F. P. Keen. 1960. BIOLOGY AND CONTROL OF THE WESTERN PINE BEETLE. U. S. Dep. Agric. Misc. Publ. 800, 381 p.

Reviews published and unpublished reports on the insect with 14 reviews related to fungi, bacteria, or yeasts. The yeast Saccharomyces pini (= Pichia pini) *was a constant associate of larvae and adults.* S. pastori *rendered the phloem attractive to the insect. Yeast fermentation caused changes in the nutrient content of the phloem but produced no pathogenic bacteria or viruses in association with the insect. Two unidentified fungi were suspected of being pathogenic. One blue-stain fungus* [Ceratostomella ips (= Ceratocystis ips)] *was specific to the insect and apparently influenced the host tree response. Reports growth of decay fungi during and following insect attack.*

141. Molnar, A. C. 1965. PATHOGENIC FUNGI ASSOCIATED WITH A BARK BEETLE ON ALPINE FIR. Can. J. Bot. 43: 563–570.
Most alpine fir mortality from attacks by Dryocoetes confusus *was caused by fungi, which were probably carried into trees by the beetles. Of three* Ceratocystis *and one* Graphium, *the most virulent fungus was* C. dryocoetidis *as a* Verticicladiella *imperfect form, but tree death occurred only when necrotic lesions coalesced. Following inoculation with* C. dryocoetidis, *Engelmann spruce and lodgepole pine appeared resistant, a fact which may explain the infrequency of successful* D. confusus *attacks on these hosts.*

142. Moore, G. E. 1970. ISOLATING ENTOMOGENOUS FUNGI AND BACTERIA AND TESTS OF FUNGAL ISOLATES AGAINST THE SOUTHERN PINE BEETLE. J. Econ. Entomol. 63: 1702–1704.
Describes a method of eliminating saprophytic fungal overgrowth so that internal and nonsporulating organisms can be detected in diseased insects. Isolated fungi were Beauveria bassiana, Aspergillus flavus, Fusarium solani, Penicillium *spp.,* A. niger, *and* Trichoderma *spp. In pathogenicity tests where the first three fungi and one* Penicillium *sp. were inoculated into the beetles, all inoculated insects died in 6-10 days. Bacterial isolates from diseased beetles were* Serratia, Pseudomonas, Aerobacter, *and* Bacillus *spp.*

143. Moore, G. E. 1971. MORTALITY FACTORS CAUSED BY PATHOGENIC BACTERIA AND FUNGI OF THE SOUTHERN PINE BEETLE IN NORTH CAROLINA. J. Invertebr. Pathol. 17: 28–37.
Pathogenic microorganisms were responsible for 22 percent of the mortality of brood insects collected during sampling periods from 1966-1968. Bacteria isolated from moribund and dead beetles included Serratia marcescens, Pseudomonas aeruginosa, P. fluorescens, Bacillus thuringiensis *var.* thuringiensis, B. cereus *and* Flavobacterium *spp.; fungi isolated from both the exterior and interior of the beetles included* Beauveria bassiana, Aspergillus flavus, Cephalosporium *sp.,* Fusarium solani, Metarrhizium anisopliae, Paecilomyces *sp., and* Scopulariopsis *sp.*

144. Moore, G. E. 1972. MICROFLORA FROM THE ALIMENTARY TRACT OF HEALTHY SOUTHERN PINE BEETLES, *DENDROCTONUS FRONTALIS* (SCOLYTIDAE), AND THEIR POSSIBLE RELATIONSHIP TO PATHOGENICITY. J. Invertebr. Pathol. 19: 72–75.
Microflora of 250 healthy larvae and adults were determined by aseptically excising portions of the fore-, mid-, and hindguts and culturing them on agar. Six genera of bacteria and five genera of fungi were recovered from 178 insects. The most frequently isolated bacteria were Aerobacter aerogenes, Alcaligenes faecalis, *and* Serratia *spp.* Aspergillus *spp. and* Penicillium *spp. were the most frequent fungi, and* Candida *sp. was the only yeast recovered. Seven of the species were identical with facultative or conditioned pathogens recovered from diseased beetles in other studies.*

145. Moore, G. E. 1972. PATHOGENICITY OF TEN STRAINS OF BACTERIA TO LARVAE OF THE SOUTHERN PINE BEETLE. J. Invertebr. Pathol. 20: 41–45.
Pathogenicity was determined by inoculating healthy larvae orally. All but the three Bacillus *spp., which were previously isolated, were from both healthy and diseased beetles. The* Bacillus *spp.* (B. cereus, B. thuringiensis *var.* thuringiensis, *and* B. thuringiensis *var.* kenyae), Pseudomonas aeruginosa, P. fluorescens, *and* Serratia marcescens *were all from diseased beetles and were pathogenic.* Alcaligenes faecalis *and* Aerobacter aerogenes, *both from diseased beetles, and* A. faecalis *and* S. marcescens, *from healthy beetles, were not pathogenic.*

146. Moore, G. E., and R. C. Thatcher. 1973. EPIDEMIC AND ENDEMIC POPULATIONS OF THE SOUTHERN PINE BEETLE. U.S. Dep. Agric. For. Serv. Res. Pap. SE–111, 11 p. Southeast. For. Exp. Stn., Ashville, N. C.
Defines differences between epidemic and endemic populations of the southern pine beetle in two distinct geographical areas. Beetle populations may be lowered by encouraging the development of pathogenic organisms.

147. Morgan, F. D. 1967. *IPS GRANDICOLLIS* IN SOUTH AUSTRALIA. Aust. For. 31: 137–155.
Beetles introduced several fungi into inner bark and sapwood of Pinus radiata. *Fungi always associated with* Ips grandicollis *were* Diplodea pinea, Ceratocystis ips, *and certain yeasts.* D. pinea *and* C. ips *caused sapwood discoloration. When inoculated in sufficient quantity,* C. ips *contributed to the deaths of infected trees.*

148. Moya-Borja, G. E. 1971. SOME ASPECTS OF THE BIOLOGY AND NUTRITION OF FOUR SPECIES OF *XYLEBORUS* AMBROSIA BEETLES. Ph.D. Thesis. Univ. of Wis. 143 p. (Diss. Abstr. 31: 7350B.)
Serial sagittal sections of adults of X. posticus, X. corniculatus, *and* X. cuneatus *revealed one pair of oral mycangia for each sex. Intact oral mycangia were readily observed microscopically in callow adults of* X. ferrugineus *and* X. posticus. Fusarium solani, Cephalosporium *sp.,* Graphium *sp., an unidentified yeast, and an unidentified bacteria were isolated from mycangia of all four species and comprise their microbial complex.*

149. Nakashima, T. 1971. NOTES ON THE ASSOCIATED FUNGI AND THE MYCETANGIA OF THE AMBROSIA BEETLE, *CROSSOTARSUS NIPONICUS* BLANDFORD (COLEOPTERA: PLATYPODIDAE). Appl. Entomol. Zool. 6: 131–137.
A single spherical mycetangium is located at the back of the preoral cavity of the adult female. Sponge-like tissue containing fungal material surrounds the sphere. Absidia glauca *was isolated from fluid in the preoral cavities of all females. In a few specimens,* Cephalosporium mycophilum, C. acremonium, Chaetomium indicum, *and several bacteria were also isolated.*

150. Nakashima, T. 1972. NOTES ON THE MYCETANGIA OF THE AMBROSIA BEETLES,

PLATYPUS SEVERINI BLANDFORD AND *P. CALAMUS* BLANDFORD (COLEOPTERA: SCOLYTIDAE). Appl. Entomol. Zool. 7: 217–225. *Female adults of both species have several hundred integumentary, pitted mycetangia on the pronotum, whereas male adults have only a few of the pits. The main mycetangia of the male adult of* P. severini *are enlarged forecoxal and mesocoxal cavities not found in females.*

51. Neužilová, A. 1956. PŘÍSPĚVEK K ZNALOSTI CIZOPASNÝCH HUB KŮROVCŮ *IPS TYPOGRAPHUS.* [A CONTRIBUTION TO THE KNOWLEDGE OF THE PARASITIC FUNGUS OF *IPS TYPOGRAPHUS.*] Preslia 28: 273–275. *Examination of the bark beetle revealed four entomophagous* Beauveria *forms:* Beauveria bassiana, B. globulifera, *and* B. densa *have been frequently found in insects, but the fourth,* Spicaria farinosa, *is from an undescribed host. Mass cultures of* B. globulifera *produced good sporulation, and the fungus was utilized for successful control of the pest* Gnorimoschema ocellatellum.

52. Nilsson, T. 1973. STUDIES ON WOOD DEGRADATION AND CELLULOLYTIC ACTIVITY OF MICROFUNGI. Studia For. Suec. 104, 40 p. R. Coll. For., Stockholm. *Cavity formation, cell wall erosion, and cellulose clearing were observed in 160 fungus species, including 13* Ceratocystis *species* (brunneociliata, cana, clavata, coerulescens, crassivaginata, ips, minor, minuta, olivacea, piceae, pilifera, tetropii, *and sp. A). Two species* (piceae *and sp. A) produced cavities in secondary cell walls of birch* (Betula verrucosa) *wood fibers, but only* piceae *caused cavities in pine* (P. silvestris). Cellulolytic *activity was noted in* cava, piceae, *and* tetropii.

53. Nisikado, Y., and K. Yamauti. 1934. CONTRIBUTIONS TO THE KNOWLEDGE OF THE SAP STAINS OF WOOD IN JAPAN. II. STUDIES ON *CERATOSTOMELLA PINI* MÜNCH, THE CAUSE OF A BLUE STAIN OF PINE TREES. Ber. Ohara Inst. Landwintsch. Forsch. 6: 467–490. *Describes and illustrates the fungus* Ceratostomella pini (= Ceratocystis minor), *which was found on* Pinus densiflora *and* Pinus thumbergii. *It attacked felled trees and those already weakened by bark beetles.*

54. Nobuchi, A. 1972. THE BIOLOGY OF JAPANESE SCOLYTIDAE AND PLATYPODIDAE (COLEOPTERA). Rev. Plant. Prot. Res. 5: 61–75. *Xylomycetophagy is a highly specialized feeding habit prevalent in the tribes Xyloterini and Xyleborini of the subfamily Ipinae, in some of the Scolytidae, and in all species of the Platypodidae that occur in Japan. Included are species of the genera* Neohyorrhynchus, Sueus, Trypodendron, Indocryphalus, Xylosandrus, Xyleborus, Cnestus, Scolytoplatypus, Platypus, Crossotarsus *and* Diapus. *Spores of a symbiotic fungi are carried by beetles in specialized structures on or within their bodies; therefore safe transport of the fungus to new galleries is assured. Tunnels extend directly through bark into sapwood or heartwood. Both larvae and adults feed on ambrosia fungi growing on gallery walls.* Xyleborus seriatus *is the only species that feeds on the ambrosia fungi growing between the bark and sapwood. Damage to trees and logs is assessed according to depth and density of galleries made by invading blue-stain or wood-rotting fungi and by the black, fungus-stained galleries of the ambrosia beetles.*

155. Nobuchi, A. 1973. THE PLATYPODIDAE OF JAPAN. Bull. Gov. For. Exp. Stn. Toyko 256: 1–22. *All 18 recognized species of Platypodidae are ambrosia beetles with monogamous social organization. The mycangia of* Crossotarsus niponicus, Platypus calamus, *and* P. severini *have been described previously. Ambrosia beetles in this family and a few genera of the Scolytidae cause mechanical damage to green logs, and they facilitate the invasion of blue-stain or wood-rotting fungi. Provides keys to all species and mentions geographical distribution and host plants.*

156. Nord, J. C. 1972. BIOLOGY OF THE COLUMBIAN TIMBER BEETLE, *CORTHYLUS COLUMBIANUS* (COLEOPTERA: SCOLYTIDAE), IN GEORGIA. Ann. Entomol. Soc. Am. 65: 350–358.
The fungus Ambrosiella xylebori, *isolated from active galleries and from mycangia in male adults, may be the primary ambrosia fungus lining channels of the gallery and brood cells. It is the most luxuriant fungus in the newly excavated portions of the gallery and provides food for larvae and presumably adults.*

157. Norris, D. M. 1966. THE COMPLEX OF FUNGI ESSENTIAL TO THE GROWTH AND DEVELOPMENT OF *XYLEBORUS SHARPI* IN WOOD. Holz und Organismen. Int. Symp. Berlin-Dahlem (1965) 1: 523–529.
Investigated fungal symbionts and associates of seven species of ambrosia beetles in the genera Xyleborus, Trypodendron, Monarthrum, *and* Xyloterinus; *the species may attack* Betula, Populus, Quercus, Theobroma, *or* Ulmus. *Symbionts and associates of* Xyleborus sharpi *attacking* Theobroma *or* Ulmus *were emphasized. One species each of* Botryodiplodia, Fusarium, Paecilomyces, *and* Candida *was isolated from most ovipositional tunnels or brood galleries of* X. sharpi, *but other fungi were rarely isolated. When this beetle was reared on the nonhost species* Ulmus americana, *the same four fungi were isolated from galleries containing brood. These consistent findings indicate that the four fungi are probably essential for many ambrosia fungus complexes.*

158. Norris, D. M., and J. K. Baker. 1967. SYMBIOSIS: EFFECTS OF A MUTUALISTIC FUNGUS UPON THE GROWTH AND REPRODUCTION OF *XYLEBORUS FERRUGINEUS.* Science 156: 1120–1122.
Beetles developed from asymbiontic eggs through the adult stage on a sterilized meridic diet (I), but the resulting adults oviposited viable eggs only when a mutualistic fungus (Fusarium solani) *was inoculated into the diet. This ambrosia fungus probably synthesizes chemicals essential to insect reproduction. On another diet (II), beetles with*

bacterial symbionts still required the ambrosia fungus for reproduction. This fungus was consistently isolated from oral mycangia in the beetles and was transported to galleries constructed by the insects.

159. Norris, D. M., and J. M. Baker. 1968. A MINIMAL NUTRITIONAL SUBSTRATE REQUIRED BY *FUSARIUM SOLANI* TO FULFILL ITS MUTUALISTIC RELATIONSHIP WITH *XYLEBORUS FERRUGINEUS*. Ann. Entomol. Soc. Am. 61: 1473–1475.
Beetles given a minimal nutritional diet of cellulose, agar, water, and the fungus Fusarium solani *produced no progeny because the diet did not provide adequate nutrition for the fungus, which in turn was not adequate to ensure beetle reproduction. The addition of chemicals such as Wesson salts, sodium nitrate, wood vitamins, and dextrose resulted in a chemically defined substrate required by the symbiotic fungus to fulfill its mutualistic role as provider of the nutritional requirements of the ambrosia beetle,* X. ferrugineus.

160. Norris, D. M., J. M. Baker, and H-M Chu. 1969. SYMBIONTIC INTERRELATIONSHIPS BETWEEN MICROBES AND AMBROSIA BEETLES. III. ERGOSTEROL AS THE SOURCE OF STEROL TO THE INSECT. Ann. Entomol. Soc. Am. 62: 413–414.
Without a mutualistic fungus, Xyleborus ferrugineus *pupated in the second generation on test diets containing 0.2 g of ergosterol. Cholesterol at 0.2 g per diet batch was not an adequate source of sterol in the second fungus-free generation. Sterol requirements lacking in the diets of the first generation apparently were met by carry-over of such nutrients from the previous generation (stock culture), whose diet contained fungus.*

161. Norris, D. M., and H-M Chu. 1970. NUTRITION OF *XYLEBORUS FERRUGINEUS*. II. A HOLIDIC DIET FOR THE APOSYMBIOTIC INSECT. Ann. Entomol. Soc. Am. 63: 1142–1145.
Specimens of X. ferrugineus *were cultured in test tubes, freed of ectosymbiotes, and observed for development and for nutritional and physiological needs. Two holidic diets, one containing 10 amino acids and the other 18, were assessed for nutritional adequacy. Both were adequate, but the diet containing 10 amino acids was better. Ergosterol is the source of sterol. Reproduction is arrhenotokous, and fertilized females yield progeny with a spanandrous sex ratio.*

162. Norris, D. M., and H-M Chu. 1971. MATERNAL *XYLEBORUS FERRUGINEUS* TRANSMISSION OF STEROL OR STEROL-DEPENDENT METABOLITES NECESSARY FOR PROGENY PUPATION. J. Insect Physiol. 17: 1741–1745.
The aposymbiotic female Xyleborus ferrugineus *transmitted ergosterol or ergosterol-dependent metabolites necessary for progeny pupation. Transmission was apparently transovarial. Sterol for immature development was required in the progeny diet. When maintained on a diet containing cholesterol, maternal females were no longer able to transmit chemical components necessary for progeny pupation.*

163. Olchowecki, A., and J. Reid. 1974. TAXONOMY OF THE GENUS *CERATOCYSTIS* IN MANITOBA. Can. J. Bot. 52: 1675–1711.
Presents keys to 70 species, including 50 that occur in Manitoba, and divides them into four groups based on ascospore characteristics: Minuta, Ips, Fimbriata, and Pilifera. Keys to species for each group are based additionally on the following: character of the perithecial neck; size, color, and ornamentation of the perithecial base; presence and nature of the ostiolar hyphae; character of the conidial state; and character of the mycelia in culture. Twenty-five new species are described, and descriptions of the conidial states of three species are provided for the first time.

164. Olofinboba, M. O., and J. R. S. Lawton. 1968. AN INVESTIGATION INTO THE BIOLOGY OF THE BLUE-STAIN ORGANISM IN *ANTIARIS AFRICANA*. J. Inst. Wood Sci. 21: 6–20.
Describes experiments showing which part of the tree is susceptible to fungal development. The causal organism is Botryodiplodia theobromae, *which colonizes the wood by entering from vessels into adjacent vasicentric parenchyma, where rapid development occurs. The fungal hyphae then penetrate ray parenchyma and other xylem cells and greatly deplete the carbohydrate content of the wood.*

165. Ordish, G. 1966. PINE BARK BEETLE IN HONDURAS. Span 9: 121–123.
Discusses outbreak of Dendroctonus *spp. and suggests that the beetle's relationship with* Ceratocystis *blue stain is not symbiotic, commensal, or parasitic according to the usual definitions of these conditions; the insect merely transports the fungus to suitable host material.*

166. Osgood, E. A. 1957. A BIBLIOGRAPHY ON THE SOUTHERN PINE BEETLE, *DENDROCTONUS FRONTALIS* ZIMM. U.S. Dep. Agric. For. Serv. Res. Pap. SE–80, 19 p. Southeast. For. Exp. Stn., Asheville, N. C.
Fourteen references from 1929–1949 are given for fungi associated with the insect.

167. Parker, A. K. 1957. *EUROPHIUM*, A NEW GENUS OF THE ASCOMYCETES WITH A *LEPTOGRAPHIUM* IMPERFECT STATE. Can. J. Bot. 35: 173–179.
Describes a new species, Europhium trinacriforme, *and discusses a method for culturing on artificial media the perithecia found on the trunks of dead and dying* Pinus monticola.

168. Partridge, A. D., and D. L. Miller. 1972. BARK BEETLES AND ROOT ROTS RELATED IN IDAHO CONIFERS. U.S. Dep. Agric. Plant Dis. Rep. 56: 498–500.
Examinations of root rots caused mainly by Armillaria mellea *showed a significant association between rotting and the presence of bark beetles. The relationship was particularly evident in Douglas-fir, grand-fir, and ponderosa pine. The bark beetles were not identified.*

169. Pawsey, R. G. 1968. OBSERVATIONS ON BLUE-STAIN AND PIN-HOLE BEETLES, AND THEIR CONTROL, UN UNPEELED LOGS OF

PINUS CARIBAEA IN TRINIDAD. Commonw. For. Rev. 47: 211–224.
Chemical treatment of logs (log-ends and whole-logs) immediately after felling was not effective in controlling blue-stain. Whole-log spraying with 1.0 percent gamma B.H.C. in dieseline gave excellent control of pin-hole beetle damage, and there was evidence of an inverse relationship between resin production from cut ends of logs and blue-stain development. Bark beetles were not associated with blue-stain.

70. Peleg, B., and D. M. Norris. 1972. BACTERIAL SYMBIOTE ACTIVATION OF INSECT PARTHENOGENETIC REPRODUCTION. Nat. New Biol. 236: 111–112.
In Xyleborus ferrugineus, *both natural oocyte maturation and haploid parthenogenesis depend on bacterial symbiotes in the insect. The symbiotic bacterium isolated was placed in the genus* Staphylococcus *(see following paper).*

71. Peleg, B., and D. M. Norris. 1972. SYMBIOTIC INTERRELATIONSHIPS BETWEEN MICROBES AND AMBROSIA BEETLES. VII. BACTERIAL SYMBIONTS ASSOCIATED WITH *XYLEBORUS FERRUGINEUS*. J. Invertebr. Pathol. 20: 59–65.
Transovarially transmitted bacterial symbionts in the genus Staphylococcus *were isolated from the gut lumen of all beetle stages and were shown to invade the oocytes. The invasion was associated with initiation of nuclear division when the oocytes, unfertilized by sperm, were surrounded by the follicular wall in the ovariole. With such an oocyte activation, the bacterium apparently supercedes the sperm and enables the beetles to reproduce parthenogenetically.*

172. Peleg, B., and D. M. Norris. 1973. HAPLOID VERSUS DIPLOID *XYLEBORUS FERRUGINEUS*. I. LARVAL INSTARS, DEVELOPMENT, AND MORPHOGENESIS OF THE METATHORACIC WING. Ann. Entomol. Soc. Am. 66: 180–183.
Xyleborus ferrugineus *reared on stock cultures of fungal and bacterial symbionts had three instars for both haploid and diploid larvae. No marked differences were observed in the time required for larval development. The first distinct difference was observed in the metathoracic wings of the pupa: adult females possessed well-developed wings and were strong flyers, but the adult males had degenerate metathoracic wings and could not fly.*

173. Peleg, B., and D. M. Norris. 1973. OÖCYTE ACTIVATION IN *XYLEBORUS FERRUGINEUS* BY BACTERIAL SYMBIONTS. J. Insect Physiol. 19: 137–145.
This ambrosia beetle exhibits arrhenotokous parthenogenesis, in which the unmated female normally lays eggs that yield haploid male progeny. By invading and activating the oöcytes, bacterial symbionts may enable the beetles to reproduce asexually. Antibiotics incorporated in a sodium benzoate- or in an asorbic acid-based meridic diet significantly reduced oviposition and number of progeny of ectosymbiotic fungus-free virgin females. Bacteria were not found in the primary oöcytes of nonovipositing treated females, but when placed on an antibiotic-free diet, the females regained fertility. Their eggs contained many symbionts that were transmitted transovarially.

174. Peplinski, J. D., and W. Merrill. 1974. NONSURVIVAL OF *CERATOCYSTIS FAGACEARUM* IN FRASS OF OAK BARK BEETLES AND AMBROSIA BEETLES. Phytopathology 64: 1528–1530.
Viable propagules of the fungus were not present in the frass of oak bark beetles (Pseudopityopthorus *spp.) or ambrosia beetles* (Xyleborus saxeseni, X. xylographus, *and* Xyloterinus politus) *in Pennsylvania oaks. The oak bark beetle appears to carry the fungus internally, either in the digestive tract or in special structures such as mycangia. The percentage of effective vectors is lower than 0.4 percent, a fact that may explain the slow spreading rate of oak wilt.*

175. Person, H. L. 1931. THEORY IN EXPLANATION OF THE SELECTION OF CERTAIN TREES BY THE WESTERN PINE BEETLE. J. For. 29: 696–699.
An initial weak attraction occurs, caused by the formation of volatile oils such as aldehydes or esters—by-products of respiratory fermentation or abnormal enzyme activity in subnormal trees. These oils attract beetles from the immediate vicinity, and the beetles introduce a yeast into the inner bark. The yeast produces a fermentation strong enough to attract other beetles from a wider radius.

176. Phaff, H. J., and L. D. Carmo-Sousa. 1962. FOUR NEW SPECIES OF YEAST ISOLATED FROM INSECT FRASS IN BARK OF *TSUGA HETEROPHYLLA* (RAF.) SARGENT. Antonie van Leeuwenhoek 28: 193–207.
These yeasts were isolated from insect frass in Pacific coast hemlock and were described as Sporobolomyces singularis, Bullera tsugae, Cryptococcus skinneri *and* Candida oregonensis. Sporobolomyces singularis, *a nonpigmented species, required an amendment of the genus definition. The yeasts are probably transmitted by* Scolytus tsuga.

177. Phaff, H. J., and M. Yoneyama. 1961. *ENDOMYCOPSIS SCOLYTI*, A NEW HETEROTHALLIC SPECIES OF YEAST. Antonie van Leeuwenhoek 27: 196–202.
The natural habitat of the new species is in frass or in larvae or adults of two species of bark beetles: Scolytus ventralis, *which attacks* Abies, *and* S. unispinosus, *which attacks* Pseudotsuga.

178. Pitman, G. B. 1965. CERTAIN FACTORS AFFECTING COLONIZATION OF PONDEROSA PINE BY *IPS CONFUSUS* (LE CONTE) (COLEOPTERA: SCOLYTIDAE). Ph.D. Thesis. Oregon State Univ., Corvallis, Oregon, 217 p. (Diss. Abstr. 26: 598.)
Inoculation with the blue staining fungus Ceratocystis ips *indicated that the microorganism was aiding colonization and brood development only by reducing moisture movement and oleoresin exudation in the outer sapwood.*

179. Reid, R. W., and D. M. Shrimpton. 1971. RESISTANT RESPONSE OF LODGEPOLE PINE TO INOCULATION WITH *EUROPHIUM CLAVIGERUM* IN DIFFERENT MONTHS AND AT DIFFERENT HEIGHTS ON STEM. Can. J. Bot. 49: 349–351.

For lodgepole pines inoculated at monthly intervals between May and October, the number of trees showing a fully resistant response reached a maximum in early July and then gradually declined. When resistant lodgepole pine trees were inoculated at intervals of 6 feet starting at the groundline, the resistant response was greatest in the lowest 20 feet.

180. Reid, R. W., H. S. Whitney, and J. A. Watson. 1967. REACTIONS OF LODGEPOLE PINE TO ATTACK BY *DENDROCTONUS PONDEROSAE* HOPKINS AND BLUE STAIN FUNGI. Can. J. Bot. 45: 1115–1126.

Europhium *sp. and* Ceratocystis montia *were consistently isolated from* D. ponderosae (= D. monticolae) *and from their galleries and adjacent stem tissue. Secondary resinosis is largely responsible for tree resistance to bark beetles and blue-stain fungi. Resistance did not depend on the absence of the two fungi because both were present in successful and in unsuccessful beetle attacks. Following attacks, the amounts on nonconductive sapwood were about equal in resistant and susceptible trees, but the sapwood of resistant trees was soaked with resin. In successful attacks, the sapwood was not soaked but was colonized by blue-stain fungi.*

181. Rexrode, C. O., H. M. Kulman, and C. K. Dorsey. 1965. BIONOMICS OF THE BARK BEETLE *PSEUDOPITYOPHTHORUS PRUINOSUS* WITH SPECIAL REFERENCE TO ITS ROLE AS A VECTOR OF OAK WILT, *CERATOCYSTIS FAGACEARUM*. J. Econ. Entomol. 58: 913–916.

Parent beetles left the trees 10 to 12 days after they had constructed egg galleries. In laboratory studies, parents emerged after completing their galleries, made new attacks on fresh twigs, and fed on buds. With the spermatization technique, 2 to 20 percent of the emerging parent beetles collected in the field carried the oak wilt fungus and could therefore serve as vectors. Parents were more likely vectors than their offspring, which emerged only after the trees had become dry or were overrun by other fungi.

182. Reynolds, P. E., W. H. Smith, and K. F. Jensen. 1972. EFFECT OF CONSTANT AND FLUCTUATING TEMPERATURES ON THE *IN VITRO* GROWTH OF *CERATOCYSTIS* SPECIES. Trans. Br. Mycol. Soc. 59: 1–9.

Isolates of C. adiposa, C. pluriannulata, C. minor, C. coerulescens, *and* C. pilifera, *all from the Southeastern United States, and 14 isolates of* C. ulmi *were tested at constant 5°C increments from 15° to 35°C, with fluctuating treatments administered by varying the temperature 3°, 6°, and 9°C above and below the constant temperatures.* C. minor *grew relatively slowly at all temperatures tested but grew best at a constant 25°C and at 6° fluctuations about a 25° mean.*

183. Richards, A. G., and M. A. Brooks. 1958. INTERNAL SYMBIOSIS IN INSECTS. Ann. Rev. Entomol. 3: 37–56.

Gives a general account of internal symbiosis in insects and includes some definitions. Discusses the origin of symbiotic associations, the anatomy of hosts, and the effects of symbiotic microorganisms on insects. The Scolytids are not mentioned.

184. Richmond, J. A., C. Mills, and E. W. Clark. 1970. CHEMICAL CHANGES IN LOBLOLLY PINE, *PINUS TAEDA* L., INNER BARK CAUSED BY BLUE STAIN FUNGUS, *CERATOCYSTIS MINOR* (HEDG.) HUNT. J. Elisha Mitchell Sci. Soc. 86: 171.

Investigates changes in free amino acids, carbohydrates, and fatty acids (free and triglyceride) in inner bark of loblolly pine infected with the blue stain fungus and in uninfected inner bark. Free and triglyceride fatty acids of the fungus were also analyzed. Uninfected bark showed decreases for all properties observed. Five weeks after incubation, infected bark revealed a 36 percent decrease in the amino nitrogen content, an 80 percent decrease in carbohydrates, a three-fold decrease in triglyceride fatty acids, and a seven-fold increase in free fatty acids. The major free and triglyceride fatty acids of both the injected bark and the pure fungal cultures were identical. Infected bark revealed large amounts of resin acids.

185. Robinson-Jeffrey, R. C., and R. W. Davidson. 1968. THREE NEW *EUROPHIUM* SPECIES WITH *VERTICICLADIELLA* IMPERFECT STATES ON BLUE-STAINED PINE. Can. J. Bot. 46: 1523–1527.

Perfect states of all three species are similar; species separation is based on differences between the imperfect states. Europhium clavigerum, E. aureum *and* E. robustum *exhibit* Verticicladiella *imperfect forms, and a previously described* E. trinacriforme *was distinguished by its* Leptographium*-like form. Cleistothecia of the perfect state, were found on bark, sapwood, and in old beetle galleries of infested, blue-stained pines, including lodgepole, ponderosa, limber, and western white pine.* E. clavigerum *was found on all hosts and was isolated directly from the mountain pine beetle and* Ips *species,* E. robustum *was found on ponderosa pine and isolated from ambrosia and* Dendroctonus *beetles (no species given), and* E. aureum *was recorded on lodgepole pine only.*

186. Rösch, R., W. Liese, and H. Berndt. 1969. UNTERSUCHUNGEN ÜBER DIE ENZYME VON BLÄUEPILZEN. I. CELLULASE-, POLYGALAKTURONASE-, PEKTINESTERASE-, UND LACCASE-AKTIVITÄT. [STUDIES ON THE ENZYMES OF BLUE-STAIN FUNGI. I. CELLULASE, POLYGALACTURONASE, PECTINASE AND LACCASE ACTIVITY.] Arch. Mikrobiol. 67: 28–50.

Ceratocystis minor, Aureobasidium pullulans, *and* Alternaria humicola *were cultivated in an unbuffered nutrient solution with glucose or carboxymethyl cellulose as carbon source. When culture filtrates were used to detect cellulase, polygalactu-*

ronase, pectinesterase, and p-diphenoloxidase, each fungus produced all four enzymes. With glucose as the carbon source, the acidity increased at the beginning of fungal growth, whereas with carboxymethyl cellulose, the pH values immediately became neutral. The glucose solution produced more cellulase than the carboxymethyl cellulose one.

87. Rudinsky, J. A. 1961. FACTORS AFFECTING THE POPULATION DENSITY OF BARK BEETLES. Proc. 13th IUFRO-Cong. vol. 1, Sect. 24–11, 13 p.
Population levels of bark beetles are determined by abiotic factors such as climate, oleoresin pressure, water conduction, moisture, and temperature, and biotic factors such as parasites, predators, and fungi. Dendroctonus pseudotsugae *in Douglas-fir and* D. brevicomis, D. monticolae, *and* Ips confusus *in ponderosa pine become primary insect pests when the abiotic and biotic interrelationships are disturbed and when host conditions are suitable. Douglas-fir, infected with* Fomes pini *and exhibiting less than 1.5 atms of oleoresin exudation pressure were successfully invaded by the Douglas-fir beetle. A blue-stain fungus* (Ceratocystis *sp.*) *obstructs water conduction and lowers tree resistance to beetle attack, but* D. brevicomis *is able to overcome ponderosa pine without the usual development of blue-stain fungi.*

88. Rudinsky, J. A., and P. Svihra. 1971. THE PATTERNS OF WATER CONDUCTION IN CONIFERS. Acta Inst. For. Zvolen, Czech. 2: 369–383.
Trees under great or prolonged water stress are successfully invaded by the Douglas-fir beetle, but during rainy or cloudy weather, water balance is usually restored. High oleoresin exudation pressure then induces resinosis; the resin flow in the gallery system made by parent beetles and developing larvae stops the feeding, repels the beetles, and prevents further spread of blue-stain fungi. The tree then recovers.

89. Rumbold, C. T. 1929. BLUE-STAINING FUNGI FOUND IN THE UNITED STATES. Phytopathology 19: 597–599.
Forest trees not infested with Dendroctonus *or* Ips *had the greatest variety of blue-stain fungi. Trees infested with either of these beetles contained the blue-stain fungus specific for that beetle.*

90. St. George, R. A., and J. A. Beal. 1929. THE SOUTHERN PINE BEETLE: A SERIOUS ENEMY OF PINES IN THE SOUTH. U. S. Dep. Agric. Farmers' Bull. 1586, 18 p.
Contains an early statement associating a blue-stain fungus with trees killed by the beetle.

91. Salonen, K. 1966. OBSERVATIONS ON *IPS SEXDENTATUS* (BOERN.) (COL., SCOLYTIDAE) AS A BLUER OF TIMBER AT INARI (INL) IN THE SUMMER OF 1965. Ann. Entomol. Fenn. 32: 88–96.
Extensive blue stain was recorded in Scotch pine sapwood associated with attack and larval development of I. sexdentatus *in Finland. Depth of staining ranged from 0.1 to 15.0 mm and appeared to be controlled by the amount of moisture in the sapwood. Stain fungi appeared to be* Tuberculariella ips *and* Ophiostoma brunneo-ciliatum. *When the temperatur was near 0°C, fungal development ceased.*

192. Saunders, J. L., and J. K. Knoke. 1967. DIETS FOR REARING THE AMBROSIA BEETLE *XYLEBORUS FERRUGINEUS* (FABRICIUS) *IN VITRO*. Science 157: 460, 463.
Female ambrosia beetles were reared successfully on an artificial diet when their associated fungus, a species of Fusarium, *was not inhibited.*

193. Saunders, J. L., J. K. Knoke, and D. M. Norris, Jr. 1967. ENDOSULFAN AND LINDANE RESIDUES ON THE TRUNK BARK OF *THEOBROMA CACAO* FOR THE CONTROL OF *XYLEBORUS FERRUGINEUS*. J. Econ. Entomol. 60: 79–82.
Describes chemical treatments to control a vascular wilt incited by the fungus Ceratocystis fimbriata, *generally associated with* Xyleborus ferrugineus. *Endosulfan residue sufficient for beetle control remained 20 weeks after treatment. Lindane residue diminished rapidly after 4 weeks.*

194. Saunders, J. L., D. M. Norris, and J. K. Knoke. 1967. INSECT-HOST TISSUE INTERRELATIONS BETWEEN *XYLEBORUS FERRUGINEUS* (COLEOPTERA: SCOLYTIDAE) AND *THEOBROMA CACAO* IN COSTA RICA. Ann. Entomol. Soc. Am. 60: 419–423.
Wood deterioration was retarded in beetle-infested zones. The fact that a wood preservative was produced by either the beetle, the associated fungi, or the host may indicate an evolved provision for maintaining conditions satisfactory for brood development. Infested trunks supported development for 2-3 months after an infestation by the vascular pathogen Ceratocystis fimbriata, *which caused foliage wilt.*

195. Savory, J. G., R. G. Pawsey, and J. S. Lawrence. 1965. PREVENTION OF BLUE-STAIN IN UNPEELED SCOTS PINE LOGS. Forestry 38: 59–81.
Effective control of blue-stain degrade in logs can be accomplished only by treating the logs with chemicals that prevent attacks by bark beetles—the transmittors of Ceratocystis *spp. and other bluing fungi. Whole-log treatments with a combined fungicide and insecticide in a water emulsion [2 percent Santobrite (active ingredient 90 percent sodium pentachlorophenate), 2 percent borax, and 0.75 percent gamma BHC] applied to the point of run off gave very good protection for 3 months. End treatments with fungicides followed by whole-log treatments with insecticides were also effective.*

196. Schmitz, R. F., and J. A. Rudinsky. 1968. EFFECT OF COMPETITION ON SURVIVAL IN WESTERN OREGON OF THE DOUGLAS-FIR BEETLE. For. Res. Lab. Res. Pap. 8, 42 p. Ore. State Univ., Corvallis, Oreg.
Attacks ceased when the temperature dropped below 50°F or during rain. No differences were observed in the number of eggs laid at different attack densities (one to three attacks per square foot), but maximum brood survival occurred at densities of 1.0 to 1.9 attacks per square foot. The larvae avoided areas of the phloem that contained white

fungal mats or the blue stain fungus; thus, the direction of the larval mines is controlled in part by fungal growth. Intraspecific competition was a factor in natural control, but interspecific competition was not.

197. Schneider, I. A., and J. A. Rudinsky. 1969. MYCETANGIAL GLANDS AND THEIR SEASONAL CHANGES IN *GNATHOTRICHUS RETUSUS* AND *G. SULCATUS*. Ann. Entomol. Soc. Am. 62: 39–43.
Fungus repositories of the male beetles are relatively primitive but contain a glandular epithelium. The gland cells are activated at the end of hibernation and secrete through funnel-shaped openings into the lumen of the mycetangium during the flight period. Development of the symbiotic fungi is synchronized with that of the glands. Fungus cells passively gain entrance into the mycetangium by beetle movement in the gallery at the end of hibernation; the cells proliferate in the presence of the secretion and are disseminated in the new galleries. By the time the beetles are preparing brood gallery, the gland cells are depleted and begin to deteriorate.

198. Scott, D. B., and J. W. Du Toit. 1970. THREE NEW *RAFFAELEA* SPECIES. Trans. Br. Mycol. Soc. 55: 181–186.
The principal fungi occurring in symbiosis with two ambrosia beetles in South Africa are described and assigned to newly described species in Raffaelea. R. albimanens *sp. nov. and* R. hennebertii *sp. nov. are associated with* Platypus externedentatus, *and* R. arxii *sp. nov., with* Xyleborus torquatus.

199. Shepherd, R. F., and J. A. Watson. 1959. BLUE STAIN FUNGI ASSOCIATED WITH THE MOUNTAIN PINE BEETLE. Can. Dep. Agric. For. Biol. Div. Bimon. Prog. Rep. 15(3): 2–3.
Blue-stain fungi (unidentified) are usually introduced into a green tree at the time of attack by adult beetles, which the fungi help to establish by reducing resin flow and blocking water movement in the tree. This study indicates that the fungi probably reduce resin production by utilizing the cell contents and stored food of parenchyma cells, which conduct the food from the phloem into the sapwood. The fungi restrict water conduction by destroying the ray parenchyma cells, which partially control water movement.

200. Shrimpton, D. M. 1973. EXTRACTIVES ASSOCIATED WITH WOUND RESPONSE OF LODGEPOLE PINE ATTACKED BY THE MOUNTAIN PINE BEETLE AND ASSOCIATED MICROORGANISMS. Can. J. Bot. 51: 527–534.
Describes the lodgepole pine response to sapwood invading fungi vectored by bark beetles. First, an initial flow of oleoresin escapes into adjacent tissues from resin ducts severed by the attacking beetles; next, a synthesis of monoterpene occurs within parenchyma cells adjacent to the beetle gallery; finally, sugars and fatty acids are utilized by the fungi. The total amount of terpene increased to levels well above those normal for sapwood and heartwood. All components found in the response were normal constituents of heartwood. Free acids, phenolics, and neutral components increased much more slowly than terpenes and achieved a final concentration about equal to that in heartwood. Free sugar levels decreased. No unusually high or low levels of any compound were observed in response to the wound, except for a high level of phellandrene.

201. Shrimpton, D. M. 1973. AGE- AND SIZE-RELATED RESPONSE OF LODGEPOLE PINE TO INOCULATION WITH *EUROPHIUM CLAVIGERUM*. Can. J. Bot. 51: 1155–1160.
The reactions of 530 trees between 8 and 140 years old were classified as resistant or nonresistant after a summer inoculation with E. clavigerum, *the fungus associated with the mountain pine beetle. Trees between 31 and 50 years old had the greatest frequency of potentially resistant individuals. The youngest (age 10-30) and oldest (age 90-120) trees showed a decreasing frequency of resistant individuals. Trees potentially capable of preventing bark beetles from colonizing their stem tissues generally had better diameter growth and thicker phloem than nonresistant trees.*

202. Shrimpton, D. M., and R. W. Reid. 1973. CHANGE IN RESISTANCE OF LODGEPOLE PINE TO MOUNTAIN PINE BEETLE BETWEEN 1965 AND 1972. Can. J. For. Res. 3: 430–432.
In 1965, lodgepole pines near Radium, B.C., were graded for resistance to mountain pine beetles by evaluating their response to inoculation with a bluestain fungus normally transported by the beetle. Trees surviving the first treatment were inoculated again in 1972, and the resistance of each was reevaluated. Most trees graded nonresistant in 1965 had died by 1972; whereas, most trees originally rated resistant were still alive and were again rated resistant.

203. Shrimpton, D. M., and J. A. Watson. 1971. RESPONSE OF LODGEPOLE PINE SEEDLINGS TO INOCULATION WITH *EUROPHIUM CLAVIGERUM*, A BLUE STAIN FUNGUS. Can. J. Bot. 49: 373–375.
Point inoculations of the fungus in 4-6 year old seedlings produced resinous reactions similar to those observed in mature trees following artificial or natural introduction of the fungus with the mountain pine beetle. No blue stain developed in the sapwood of any of the inoculated seedlings. Sixty days after inoculation, the resinous tissues of the seedlings contained 58 percent β-phellandrene, 22 percent 3-carene, 12 percent β-pinene, 4 percent camphene, 2 percent α-pinene, and traces of other terpenes. The phenolics identified were pinosylvin, pinosylvin monomethylether, pinobanksin, and pinocembrin. Identical compounds are present in mature trees showing resistant reactions.

204. Shrimpton, D. M., and H. S. Whitney. 1968. INHIBITION OF GROWTH OF BLUE STAIN FUNGI BY WOOD EXTRACTIVES. Can. J. Bot. 46: 757–761.
*Two blue-stain fungi (*Ceratocystis montia *and* Europhium *sp.), both commonly associated with mountain pine beetle attacks on lodgepole pine,*

evoked a resinous reaction in sapwood of resistant trees. Both fungi were inhibited in vitro *by the resinous sapwood, but nonresinous sapwood stimulated fungal growth. The fact that acetone extracts and volatile substances from resinous and nonresinous sapwood inhibited fungal growth suggests that inhibitors are present in both but that the degree of inhibition is determined by the amount of inhibitors present.* C. montia *is apparently important in establishing an initial infection court for the complete fungal complex carried by the beetle.*

05. Spaulding, P. 1961. FOREIGN DISEASES OF FOREST TREES OF THE WORLD. U. S. Dep. Agric., Agric. Handb. 197, 361 p.
Lists pathogenic diseases of forest trees according to causal agents (viruses, bacteria, and fungi); also lists hosts, pathogenicity, and range. Of the seven Ceratocystis *species listed, five* (C. ips, C. minor, C. pilifera, C. tetropii, *and* C. ulmi) *are said to be associated with bark beetles.*

06. Stark, R. W., and J. H. Borden. 1965. OBSERVATIONS ON MORTALITY FACTORS OF THE FIR ENGRAVER BEETLE, *SCOLYTUS VENTRALIS* (COLEOPTERA: SCOLYTIDAE). J. Econ. Entomol. 58: 1162–1163.
Data obtained from dissection of 505 Scolytus ventralis *galleries in three white fir trees accounted for 78.6 percent larval mortality. Predation and competition contributed 65.8 percent, parasites 4.9 percent, and a fungus, 7.9 percent. The fungus identified as* Oedocephalum *sp., contributed to the deaths of two trees. It is not known if the fungus is "entomogenous," since the genus is reportedly saprophytic on plant material; however, the fungus was found colonizing complete larvae.*

07. Stark, R. W., and F. W. Cobb, Jr. 1969. SMOG INJURY, ROOT DISEASES AND BARK BEETLE DAMAGE IN PONDEROSA PINE. Calif. Agric. 23: 13–15.
Photochemical oxidants (smog) caused serious injury to ponderosa pine in the San Bernardino Mountains of southern California. Smog injury apparently renders the trees more susceptible to attack by two destructive forest insects, the western pine beetle (Dendroctonus brevicomis) *and the mountain pine beetle* (D. ponderosae). *Photochemical oxidant injury to ponderosa pine reduces the oleoresin yield, the rate of resin flow and oleoresin exudation pressure, the moisture content of sapwood and phloem, and the phloem thickness, all of which are important in defending trees against bark beetles. Infection of the trees by root disease fungi, particularly* Fomes annosus *and* Verticicladiella wagenerii, *produced similar injuries along with the resulting increases in bark beetle attacks.*

08. Stevens, R. E., D. B. Cahill, C. K. Lister, and G. E. Metcalf. 1974. TIMING CACODYLIC ACID TREATMENTS FOR CONTROL OF MOUNTAIN PINE BEETLE IN INFESTED PONDEROSA PINES. U. S. Dep. Agric. For. Serv. Res. Note RM–262, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.
Careful timing is critical in the post-attack application of cacodylic acid against beetle brood. Although bluestain development was initially used as one of the guidelines for determining the optimal time to apply the acid, the chances for successful beetle control are poor by the time bluestain is detectable. The length of the larval mines is the best indicator of when to apply the acid, which should be introduced into infested trees before the mines exceed 0.5 inch.

209. Stevens, R. E., C. A. Myers, W. F. McCambridge, G. L. Downing, and J. G. Laut. 1974. MOUNTAIN PINE BEETLE IN FRONT RANGE PONDEROSA PINE: WHAT IT'S DOING AND HOW TO CONTROL IT. U. S. Dep. Agric. For. Serv. Gen. Tech. Rep. RM–7, 3 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.
Beetles have a 1-year life cycle. They attack new trees in midsummer and carry a blue stain fungus that hastens tree death. Successfully attacked trees die almost immediately but do not fade for nearly a year. Combined programs of direct control, logging of infested trees, preventative silviculture, and individual tree protection are proposed as suitable control methods.

210. Struble, G. R. 1937. THE FIR ENGRAVER BEETLE, A SERIOUS ENEMY OF WHITE FIR AND RED FIR. U. S. Dep. Agric. Circ. 419, 15 p.
Within 4 to 6 days after the start of an egg gallery, a yellowish-brown discoloration of the cambium layer appears, extending vertically from each side of the gallery. The fungus that causes the stain is Trichosporium symbioticum, *which spreads in advance of the feeding larvae and dries the cambium layer.*

211. Strzelczyk, A., and A. Lamprecht. 1972. BADANIA NAD GRZYBAMI POWODUJACYMI SINIZNE DREWNA SOSNOWEGO. [STUDIES ON THE BLUE-STAINING FUNGI OF PINE WOOD.] Acta Mycol. 8: 239–247.
Describes studies to determine interactions among fungi and to evaluate the susceptibility of these fungi to commonly used fungicides. Blue-staining fungi from the genera Pullularia, Hormiscium, *and* Homodendrum *were strongly inhibited by* Trichoderma *strains, but strains of* Ophiostoma (= Ceratocystis) *were less susceptible to inhibition by this antagonist. Sodium pentachlorophenolate—even at low doses—proved to be a much stronger fungicide than sodium orthophenylphenolate.*

212. Takagi, K. 1967. THE STORAGE ORGAN OF SYMBIOTIC FUNGUS IN THE AMBROSIA BEETLE *XYLEBORUS RUBRICOLLIS* EICHHOFF (COLEOPTERA: SCOLYTIDAE). Appl. Entomol. Zool. 2: 168–170.
The adult female has a pair of sac-like pockets (mycangia) containing fungal cells, located at the base of the mandibles beneath the labrum. Lining the inner surface of the mycangia are smooth cilia formed by scales or lines spaced at regular intervals. Gland-like structures covering the mycangia walls were observed but were not described in detail.

213. Takagi, K., and T. Kaneko. 1965. BIOLOGY OF SOME SCOLYTID AMBROSIA BEETLES ATTACKING TEA PLANTS. II. SPORE STORAGE ORGAN OF TEA ROOT BORER, *XYLEBORUS*

GERMANUS BLANDFORD. Jap. J. Appl. Entomol. Zool. 9: 247–248.
The organ consists of a shallow dorsal pouch in the intersegmental membrane between the pronotum and mesonotum. The stored spores are spherical and are smaller than those from galleries of the host plant. They are laid tightly in the sac at the breeding period, but few are present during overwintering. Fungus propagation probably occurs during the pre-breeding period.

214. Takagi, K., and T. Kaneko. 1965. BIOLOGY OF SOME SCOLYTID AMBROSIA BEETLES ATTACKING TEA PLANTS. III. SPORULATION OF *XYLEBORUS GERMANUS* AMBROSIA FUNGUS. Jap. J. Appl. Entomol. Zool. 9: 298–300.
The ambrosia fungus was essential to beetle development. Spores within the mycangium were readily detected in all seasons but winter and were morphologically different from those in the galleries. The optimum temperature range for sporulation of spores cultivated from gallery walls was so narrow (20-25°C) that the growth of the beetle was indirectly limited by the effect of the soil temperature on the fungus in the tea roots.

215. Taylor, J. J. 1970. A COMPARISON OF SOME *CERATOCYSTIS* SPECIES WITH *SPOROTHRIX SCHENCKII*. Mycopathol. Mycol. Appl. 42: 233–240.
Sympodulosporogenous conidial states of C. minor, C. montia, C. multiannulata, C. narcissi, C. nigrocarpa, C. perparvispora, *and* C. pilifera *were found to be morphologically indistinguishable from the conidial state of the form-genus* Sporothrix. *Cultural, morphological, and serological characteristics and virulence of the species in mice were compared to demonstrate the close similarity between the* Ceratocystis *spp. conidial states and* S. schenckii. *The first three characteristics of the* Ceratocystis *spp. were either the same or varied similarly as those observed among* S. schenckii *strains, the only exception being that* Ceratocystis *spp. hydrolyzed starch and* S. schenckii *did not. Mouse virulence tests showed slight variations in the sizes and shapes of sympodulospores and yeast-like budding forms, but no significant differences were observed.*

216. Toriello, C., and F. Mariat. 1974. ÉTUDE COMPARÉE DES POLYOSIDES DES CHAMPIGNONS *CERATOCYSTIS STENOCERAS* ET *SPOROTHRIX SCHENCKII*. COMPOSITION CHIMIQUE ET ANALYSE IMMUNOLOGIQUE. [A COMPARATIVE STUDY OF THE POLYSACCHARIDES PRODUCED BY THE FUNGI *CERATOCYSTIS STENOCERAS* AND *SPOROTHRIX SCHENCKII*. CHEMICAL NATURE AND IMMUNOLOGICAL PROPERTIES.] Ann. Microbiol. (Inst. Pasteur) 125A: 287–307.
Similar polysaccharides were synthesized by a strain of C. stenoceras, *by an asexual mutant of the same fungus pathogenic for animals, and by a strain of the hyphomycete* S. schenckii. *Both somatic and metabolic polysaccharides contained more mannose than rhamnose. Chemical and antigenic analysis showed that the three fungi are closely related.*

217. Upadhyay, H. P., and W. B. Kendrick. 1974. A NEW *GRAPHIUM*-LIKE GENUS (CONIDIAL STATE OF *CERATOCYSTIS*). Mycologia 66: 181–183.
Conidia of the Ceratocystis *most often disseminated by insect vectors such as bark beetles are introduced to the vector by the stalked spore drop. The multifarious conidial states forming spore drops have been separated into the genera* Verticicladiella, Graphium, Leptographium, Pesotum, *and the new genus* Phialographium.

218. Vaartaja, O. 1963. FUNGI ASSOCIATED WITH INSECTS IN PINE TREES. Page 11 *in* Woods and For. Dep. South Aust. Annu. Rep. 1961–62, Edited by B. H. Bednall, Adelaide.
Diplodia pini, Ceratocystis ips, *and several unidentified fungi and yeasts were common to* Ips grandicollis *and* Pinus radiata *near Adelaide, Australia.*

219. Vaartaja, O. 1967. THE COMMON FUNGAL ASSOCIATES OF THE BARK BEETLE, *IPS GRANDICOLLIS*, IN *PINUS RADIATA* IN SOUTH AUSTRALIA. Aust. For. Res. Inst. 2(4): 40–43.
Reports the first record of Ceratocystis ips *on* Pinus radiata. *Plantings of nonstained bark and wood from infested trees of parent galleries and of older galleries with larvae and adults showed that* C. ips *was intimately (>50 percent) associated with the insect. The fungus was often isolated from the* Leptographium *fruiting structures on bark or wood, and* C. pilifera *was occasionally isolated from this habitat.* Macrophoma sabinea *was associated (>50 percent) with nonstained bark and wood on infested trees. Unidentified yeasts were commonly (>50 percent) associated with new galleries, larvae, and adults. No Basidiomycetes were isolated.*

220. Vasil'ev, O. A. 1968. K VOPROSU OB ISPOL'ZOVANII ANTAGONIZMA GRIBOV I BAKTERII DYLA ZASHCHITY DREVESINY. [USING THE ANTAGONISM OF FUNGI AND BACTERIA FOR THE PROTECTION OF WOOD.] Nauch. Tr. Leningrad Lesotekh. Akad. 110: 28–33 [Bio. Abstr. 88862, 1968].
An unidentified bacterial strain from sapwood of rafted pine logs and a fungus, Trichoderma viride, *either suppressed or completely stopped the growth of eight species of blue-stain fungi including* Ceratocystis minor. *Both organisms might be used to develop methods of protecting coniferous trees against wood staining fungi.*

221. Verrall, A. F. 1939. RELATIVE IMPORTANCE AND SEASONAL PREVALENCE OF WOOD-STAINING FUNGI IN THE SOUTHERN STATES. Phytopathology 29: 1031–1051.
Seven fungi found to cause major stain damage in southern trees were Endoconidiophora coerulescens, Ceratostomella (= Ceratocystis) pluriannulata, Diplodia natalensis, *and* Graphium ridigum *in hardwoods and* C. pilifera, C. ips, D. natalensis, *and* Diplodia *sp. in pines. Highest incidences of* D. natalensis *occurred during the hot summer months:* C. pilifera *and* E. coerulescens *occurred*

most frequently during cool months. C. ips, Diplodia *sp.,* C. pluriannulata, *and* G. rigidum *showed little seasonal fluctuation.*

2. Vité, J. P., and J. A. Rudinsky. 1962. INVESTIGATIONS ON THE RESISTANCE OF CONIFERS TO BARK BEETLE INFESTATIONS. XI. Int. Kongr. Entomol. Wein 1960. Sonderdr. Verh. II: 219–225.
Trees infected with the fungus Fomes pini *were more susceptible to mountain pine beetle attacks than uninfected ones because the oleoresin exudation pressure of diseased trees was only about half that of healthy ones. Disturbances in the normal water relation may diminish the exudation of oleoresin from the interconnected capillary system of resin ducts and may cause abnormally decreased turgidity that predisposes ponderosa pine to beetle attack.*

3. Von Schrenk, H. 1903. THE "BLUING" AND THE "RED ROT" OF THE WESTERN YELLOW PINE, WITH SPECIAL REFERENCES TO THE BLACK HILLS FOREST RESERVE. U. S. Bur. Plant. Ind. Bull. 36, 40 p.
Bluing after an attack by Dendroctonus ponderosae *is caused by the fungus* Ceratostomella (=Ceratocystis) pilifera, *which was not isolated from alimentary canals, feces, or live beetles during a limited dissemination study. The red rot disease, caused by* Polyporus ponderosus, *is not vectored by beetles but by spores in the air. Both fungi contribute to wood deterioration.*

4. Walt, J. P. van der, and E. E. Nel. 1968. *CANDIDA EDAX* SP. N. Antonie van Leeuwenhoek 34: 106–108.
Three strains of the yeast were isolated from frass recovered from deserted subcortical insect galleries in Sclerocarya caffra *growing near Groblersdal in the Transvaal.*

5. Walt, J. P. van der, and D. B. Scott. 1971. *PICHIA AMBROSIAE* SP. N., A NEW AUXILIARY AMBROSIA FUNGUS. Antonie van Leeuwenhoek 37: 15–20.
This new species was isolated from the linings of freshly opened tunnels and from the larval cradles of the xylomycetophagous scolytids, Platypus externedentatus, P. sampsoni, *and* Xyleborus torquatus. Pichia ambrosiae *may be a common component of the ectosymbiontic flora of these beetle species, which infest both indigenous and exotic trees in the coastal region of northern Natal.*

26. Walt, J. P. van der, and D. B. Scott. 1971. *SACCHAROMYCOPSIS SYNNAEDENDRA*, A NEW YEAST FROM SOUTH AFRICAN INSECT SOURCES. Mycopathol. Mycol. Appl. 44: 101–106.
Describes a new species isolated in northern Natal from walls of tunnels excavated by Platypus externedentatus *in* Tabernaemontana ventricosa *and from tunnels of* Xyleborus *sp. in* Rapanea melanophloeos *and* Nuxia floribunda, *near Knysna, Cape Providence.*

27. Walt, J. P. van der, and D. B. Scott. 1971. *PICHIA XYLOPSOCI*, A NEW YEAST FROM SOUTH AFRICAN INSECT SOURCES. Mycopathol. Mycol. Appl. 44: 321–324.
The species was recovered from tunnels excavated by the beetle, Xylopsocus capucinus, *in* Ficus sycomorus *and* Celtis africana, *on the north coast of Natal.*

228. Walt, J. P. van der, D. B. Scott, and W. C. van der Klift. 1971. FIVE NEW *TORULOPSIS* SPECIES FROM SOUTH AFRICAN INSECT SOURCES. Antonie van Leeuwenhoek 37: 461–471.
Five new yeast species, Torulopsis dendrica, T. philyla, T. silvatica, T. insectalens, *and* T. nemodendra, *were recovered from Cerambycid, Platypid, and Scolytid beetle infestations in indigenous trees in Natal and the Cape Province in South Africa.*

229. Walt, J. P. van der, D. B. Scott, and W. C. van der Klift. 1971. FOUR NEW, RELATED *CANDIDA* SPECIES FROM SOUTH AFRICAN INSECT SOURCES. Antonie van Leeuwenhoek 37: 449–460.
Four new yeast species (Candida hylophila, C. dendronema, C. silvanorum *and* C. entomophila) *were recovered from Bostrichid, Cerambycid, Scolytid, and Platypid beetle infestations of indigenous trees in the Transvaal, Natal, and the Cape Province in South Africa.*

230. Weiser, J. 1970. THREE NEW PATHOGENS OF THE DOUGLAS FIR BEETLE, *DENDOCTONUS PSEUDOTSUGAE: NOSEMA DENDROCTONI* N. SP., *OPHRYOCYSTIS DENDROCTONI* N. SP., AND *CHYTRIDIOPSIS TYPOGRAPHI* N. COMB. J. Invertebr. Pathol. 16: 436–441.
Three new protozoan parasites and a fungal parasite were found in Douglas-fir beetles. Knowledge of diseases of bark beetles is based chiefly on a few studies of diseases occurring in European scolytids. Protozoan infection rates are low, and the fungus Beauveria bassiana *in adults causes sporadic, nonspecific infection. Bacteria usually appear only in larvae exposed to extreme physical conditions. Laboratory tests indicated that these associated bacteria do not cause mortality except when applied in very high dosages.*

231. Wertz, H. W., J. M. Skelly, and W. Merrill. 1971. *CERATOCYSTIS FAGACEARUM* NOT TRANSMITTED BY AMBROSIA BEETLES. Phytopathology 61: 1185–1187.
Monarthrum fasciatum, Xyleborus saxeseni, *and* X. xylographus *did not attack or transmit* Ceratocystis fagacearum *to healthy red oak seedlings, saplings, or mature trees.* Xyloterinus politus *attacked healthy red oaks of all ages and tunneled into the xylem but did not transmit the pathogen.*

232. Whitney, H. S. 1971. ASSOCIATION OF *DENDROCTONUS PONDEROSAE* (COLEOPTERA: SCOLYTIDAE) WITH BLUE STAIN FUNGI AND YEASTS DURING BROOD DEVELOPMENT IN LODGEPOLE PINE. Can. Entomol. 103: 1495–1503.
Describes the physical association between the beetle and its associated microorganisms: the blue-stain fungi Ceratocystis montia *and* Europium clavigerum *and the yeasts* Pichia pini, Hansenula capsulata, *and* H. holstii. *The association was investigated in single broods reared in bolts of lodgepole pine* (Pinus contorta *var.* latifolia). *Eggs*

about to hatch and first-instar larvae were always contiguous with the microorganisms; newly laid eggs and larvae of the second, third, and fourth instars were not. During pupation, blue-stain fungi and yeasts colonized pupal chamber walls; when contacted by tenerals, the microorganisms were transferred to a new generation of insects. The necessity for physical contact between the insect and the microorganisms supports the hypothesis of their symbiotic relationship.

233. Whitney, H. S., and R. A. Blauel. 1972. ASCOSPORE DISPERSION IN *CERATOCYSTIS* SPP. AND *EUROPHIUM CLAVIGERUM* IN CONIFER RESIN. Mycologia 64: 410–414.
Dispersal by resin is probably important for inoculation and infection of these fungi in coniferous hosts. Cirri of the following fungi dispersed into single ascospores in pine or fir resin: Ceratocystis bicolor, C. fimbriata, C. ips, C. major, C. minor, C. minuta, C. minuta-bicolor, C. montia, *and* C. pilifera; *ascospore masses of* Europhium clavigerum *dispersed in the same manner. Only* C. fimbriata *and* C. pilifera *did not disperse in water. Cirri of* C. leucocarpa *dispersed in water but not pine resin, and those of* C. montia *dispersed in 12 of 25 substances tested and germinated on water agar only when resins, water, and undecane were used as dispersing agents. Germination of* C. minor *was not inhibited on water agar when either ponderosa pine or white fir resin was the dispersing agent. Describes a technique for obtaining single ascospore cultures following dispersal in resin; the method should be useful for investigating genetic variability.*

234. Whitney, H. S., and F. W. Cobb, Jr. 1972. NONSTAINING FUNGI ASSOCIATED WITH THE BARK BEETLE *DENDROCTONUS BREVICOMIS* (COLEOPTERA: SCOLYTIDAE) ON *PINUS PONDEROSA*. Can. J. Bot. 50: 1943–1945.
Three fungi—Ceratocystis nigrocarpa, *an unidentified hyphomycete, and an unidentified basidiomycete—were isolated from extensive nonstained areas of sapwood; the two unidentified fungi were also present in the thoracic mycangium of the female beetle. Nonstaining fungi may assist in the disruption of the conducting system of ponderosa pine attacked by the beetle and may contribute to tree death.* C. minor *was isolated from scattered patches of blue-stained sapwood. The staining fungus* C. minor *and the three nonstaining fungi appeared to be mutually exclusive.*

235. Whitney, H. S., and S. H. Farris. 1970. MAXILLARY MYCANGIUM IN THE MOUNTAIN PINE BEETLE. Science 167: 54–55.
A mycangium was located in the cardines of male and female Dendroctonus ponderosae, *but no gland cells were reported with the structure, which resembled mycangia in several species of* Trypodendron *ambrosia beetles. Blue-stain fungi and yeasts associated with beetle attacks were cultured after being isolated from the mycangia of 32 unsexed insects. Five mycangia contained the blue-stain fungus* Ceratocystis montia, *and 16 contained* Europhium clavigerum, *also a blue-stain fungus; 4 contained* Trichoderma *spp.; 3 contained* Penicillium *spp.; and 2 contained* Cladosporium *spp.; 18 contained yeasts (mainly* Pichia pini, Hansenula capsulata, *or* H. holstii); *3 mycangia yielded only yellow bacterial colonies, and 2 did not yield any microorganisms. Some mycangia that yielded the blue-stain fungi also yielded one or two yeasts, but the two blue-stain fungi were never found in the same mycangium; the nonstaining fungi were usually solitary.*

236. Wickerham, L. J. 1960. *HANSENULA HOLSTII*, A NEW YEAST IMPORTANT IN THE EARLY EVOLUTION OF THE HETEROTHALLIC SPECIES OF ITS GENUS. Mycologia 52: 171–183.
Hansenula holstii *is the most primitive heterothallic species of the genus, and its counterpart among the homothallic species is* H. capsulata. *Both are found in coniferous trees and bark beetles;* H. holstii *is associated with* Dendroctonus engelmanni. *Neither yeast forms diploid cells in nature, but both can be induced to do so in the laboratory.*

237. Wickerham, L. J., and K. A. Burton. 1961. PHYLOGENY OF PHOSPHOMANNAN-PRODUCING YEASTS. I. THE GENERA. J. Bacteriol. 82: 265–268.
Primitive yeasts of the genera Hansenula, Pichia, *and* Pachysolen *are transported to their sap substrate by bark beetles. The yeasts produce extracellular phosphorylated mannans, which through their adhesive quality enable the yeasts to adhere to insects boring through the bark. The yeasts in turn provide food for beetles and their brood. This relationship between the yeast and the beetle is one of balanced symbiosis.*

238. Wilcox, W. W. 1970. ANATOMICAL CHANGES IN WOOD CELL WALLS ATTACKED BY FUNGI AND BACTERIA. Bot. Rev. 36: 1–28.
Reviews papers describing the actions of blue-stain and mold fungi in timber. Many such fungi are transmitted to the trees by insects but apparently cause little damage to the structure of the wood they inhabit. Hyphae may be present in most wood elements and are usually most numerous in ray parenchyma cells. Penetration is primarily through pits; hyphae pass directly through the torus, but bore hyphae bore holes through tracheids and fibers, a more complex process than pit penetration. Bore hyphae are smaller than the other hyphae and may actually form from an appressorium. Penetration through pits tori and the cell walls may be primarily mechanical.

239. Wilkinson, R. C. 1968. REPRODUCTION AND DIET IN THREE SPECIES OF *IPS* BARK BEETLES. Page 83 *in* Fla. Inst. Food and Agric. Ser. Ann. Res. Rep., Univ. of Fla., Gainesville.
The yeasts Hansenula holstii *and* Pichia pini, *isolated from* Ips avulsus, *suppressed the growth and spore production of the blue stain fungus* (Ceratocystis ips), *also carried by this beetle. Of the 12 fatty acids identified by chromatographic analysis of* Ips calligraphus *life forms, C16 and C18:1 compounds were present in highest concentrations.*

240. Wilson, M. 1922. THE BLUING OF CONIFEROUS TIMBER. Trans. Roy. Scot. Arboric. Soc. 36: 82–92.

Reviews early information on blue-stain fungi. In Pinus ponderosa *severely attacked by* Dendroctonus ponderosae, *the blue coloration of the wood appeared to spread from the beetle holes, perhaps because the beetles form channels for hyphae to pass more deeply into sapwood.*

1. Wood, D. L. 1972. SELECTION AND COLONIZATION OF PONDEROSA PINE BY BARK BEETLES. *In* Insect/Plant Relationships. Edited by H. F. van Emden. Symp. R. Entomol. Soc. London 6: 101–117.

Cites four references and reviews current knowledge on associations of Dendroctonus brevicomis *with several* Ceratocystis *spp. and yeasts. States that most studies of host resistance have ignored the phytopathogen-host tree relationships and argues that effects of physio-chemical properties of the host on the beetle and the pathogen must be considered.*

2. Wright, E. F., and R. F. Cain. 1961. NEW SPECIES OF THE GENUS *CERATOCYSTIS.* Can. J. Bot. 39: 1215–1230.

Describes and illustrates four new species of the genus Ceratocystis (C. europhioides, C. brunneocrinita, C. falcata, *and* C. sagmatospora). *Many fungi in this genus possess dark-colored hyphae that cause blue stain discoloration. Beetles associated with these fungi are agents for dispersing spores.*

3. Yearian, W. C., R. J. Gouger, and R. C. Wilkinson. 1972. EFFECTS OF THE BLUESTAIN FUNGUS, *CERATOCYSTIS IPS,* ON DEVELOPMENT OF *IPS* BARK BEETLES IN PINE BOLTS. Ann. Entomol. Soc. Am. 65: 481–487.

The bluestain fungus Ceratocystis ips *was consistently associated with and transmitted by* Ips avulsus, I. calligraphus, *and* I. grandicollis, *all infesting* Pinus *species in Florida. In typical slash pine logs* (Pinus elliottii *var.* elliottii) *containing blue-stain innoculated and stain-free* I. avulsus *populations, no significant differences were found in egg gallery length, brood size, brood composition, pupal weight, or fecundity. Similar results were usually obtained with* I. calligraphus *and* I. grandicollis. *Bluestain-free populations of all three species were reared successfully through three to four successive generations in fungus-free slash pine logs. Oviposition was inhibited when pine logs were inoculated with* C. ips *8 days prior to the introduction of adults.*

244. Zimmerman, G. 1973. DIE PILZFLORA EINIGER IM HOLZ LEBENDER BORKENKAFER. [THE FUNGI OF SOME WOOD-INHABITING BARK BEETLES.] Mater. Org. 8: 121–131.

Ambrosiella hartigii, Fusarium javanicum, Ceratocystis *sp.*, Penicillium citrinum, Penicillium *sp.*, Trichoderma viride, Aspergillis *sp., and a* Sphaeropsidales *fungus were isolated from* Anisandrus dispar *galleries in* Acer pseudoplatanus; F. javanicum *was often isolated apart from the* Ambrosiella *fungus.* Ceratocystis bacillospora, C. torulosa, C. piceae, Ambrosiella ferruginea, Gliocladium roseum, Torula *sp.*, Penicillium *sp.*, T. viride, Graphium penicillioides, Graphium *sp., a* Sphaeropsidales, *and* Bjerkandera adusta *were isolated from* Xyloterus domesticus *in* Fagus sylvatica. Ascoidea hylecoeti, C. bacillospora, Ceratocystis *sp.*, G. penicillioides, Graphium *sp., bacteria, yeasts, and a* Sphaeropsidales *were isolated from galleries of* Hylecoetus dermestoides *in* F. sylvatica. The fungus F. javanicum *caused a pathogenic reaction in the shoots of tomato plants.*

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About 250 references, with comprehensive subject index.

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A Computer Program For Variable Density Yield Tables For Loblolly Pine Plantations

CLIFFORD A. MYERS

Southern
Forest
Experiment
Station

SUMMARY

The computer program described here uses relationships developed from research on loblolly pine growth to predict volumes and yields of planted stands, over the site range of the species, under a wide range of management alternatives. Timing and severity of thinnings, length of rotation, and type of harvest can be modified to compare the effects of various management strategies on wood yield. The program can be modified readily for other conditions or species.

Additional keywords: Timber management, forest management, simulation, *Pinus taeda*.

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A Computer Program For Variable Density Yield Tables For Loblolly Pine Plantations

CLIFFORD A. MYERS

INTRODUCTION

Most decisions in forest management require predictions of growth and yield. Managers plan thinnings to increase volume and value of future growth; they schedule harvest cuts to maximize returns. Sound planning must be based on good estimates of future yield, not only for one set of management actions but for enough possible alternative plans to assure that optimum choices are made. Personal experience, past production records, and published yield tables from research plots afford a basis for such predictions, but they usually apply to single combinations of stand and management options.

Described here is a computer program that uses relationships developed from research on loblolly pine (Pinus taeda L.) growth to predict volumes and yields of planted stands, over the site range of the species, under a wide range of management alternatives. The program estimates yields in cubic feet, board feet, and cords per acre, together with numbers of trees, their mean diameter and height, and basal area. It prints these values as predicted for specified time intervals, and immediately before and after each scheduled cut or thinning. Timing and severity of thinnings, length of rotation, and type of harvest (clearcut, seed-tree, two- or three-cut shelterwood) can be modified to compare the effects of various management measures on wood yield. The program can serve as a part of other programs that simulate forest management activities and aid in preparing timber management plans (Myers 1973, 1974).

The program prints a yield table for each stand (uniform in site quality, species, stand structure, and age) for which a single set of management options is specified. The stand may be hypothetical, with assumed initial spacing, or an actual stand for which age, site index, and current measurement statistics are available. Alternative yield tables for an initial stand can be developed by changing one or more management options.

The program thus inexpensively prints expected amounts of thinnings and harvest cuts for such combinations of management actions as may be of interest. Estimates of costs and returns based on such growth projections afford guides to optimum management decisions. In effect, such projections permit the manager to examine probable future impacts of contemplated operations, to consider changes, and to study their effects before money is spent on them.

The program, YLDTBL, written in ANS standard FORTRAN IV, has been tested on XEROX 560, CDC 6400, and UNIVAC 1108 computers. Readily available equations and data are incorporated in the program. Each equation and constant should be checked for local applicability for use in management planning for specific ownerships. Procedures for any necessary modifications are outlined in the Program Modifications section.

DESCRIPTION OF PROGRAM YLDTBL

Program YLDTBL consists of a main program and six subroutines. Operations performed by each routine are described below and identified by comment statements in the listing of the program in Appendix 1. Subsequent sections of this paper describe the input variables and the

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Myers is Chief Silviculturist at the Wildlife Habitat and Silviculture Laboratory, which is maintained at Nacogdoches, Texas, by the Southern Forest Experiment Station, Forest Service—USDA, in cooperation with the School of Forestry, Stephen F. Austin State University equations used to compute growth, mortality, and volumes.

Main Program

The main program performs the following operations:

1. Reads the number of stands to be processed and checks that this number is greater than zero. An error message is printed, and the entire job is terminated if a zero or negative number is found.
2. Calls subroutine BEGIN to initiate processing of each stand.
3. Checks five variables of each set of stand data for unwanted zero values. An error message is printed, and processing of the stand terminates if errors are found.
4. Determines from input variables the final age to be reported in each yield table.
5. Calls subroutines CUTS, TABLE, and PROJ in the sequence appropriate to the type and frequency of cuttings to be simulated. These three subroutines simulate the cuttings, write the results of the operations, and compute growth projections.
6. Adds volumes of the final cut to the yields from earlier removals and writes the totals at the bottom of the volume columns of the yield tables.

Subroutine BEGIN

Operations performed by BEGIN are as follows:

1. Assigns a value of zero to 26 variables to clear computer memory of data from previous computations.
2. Reads four data cards to enter inventory data and management options for each stand. These stand and control variables are defined in table 1.
3. Computes average height of the stand, if height is not entered as an item of stand inventory.
4. Computes a theoretical initial number of trees for the stand, for later use in a mortality equation that contains initial stand density as an independent variable.
5. Writes the main heading and column heads of each yield table.

Subroutine CUTS

CUTS simulates the thinnings and regeneration cuts called for by the variables specifying management controls. Volumes before and after partial cutting are computed and stored for later printing in the yield table.

Four regeneration methods can be simulated: (1) clearcutting, (2) seed-tree, (3) two-cut shelterwood, and (4) three-cut shelterwood. Seed-tree and shelterwood cuts are followed by computation of after-cutting values for average stand diameter (d.b.h.) and other stand variables.

Scheduled thinnings are not simulated if either of the following conditions apply:

a. Current basal area is not greater than the specified reserve after thinning.

b. Volumes removed would be less than specified minimums.

Subroutine TABLE

TABLE writes the first line of the body of each yield table. It also performs the following operations each time a partial cut is simulated:

1. Computes amounts to be removed and rounds off values for printing where required.
2. If removals equal or exceed specified minimum commercial limits, adds volumes removed to totals and stores the information.
3. Prints two lines in the body of the table to report status of the stand before and after cutting.

Table 1.—Order and contents of the data deck

Card type	Variable name	Punch card columns	Format	Description of variable
1	NSTND	1-4	I4	Number of sets of cards 2 to 5, inclusive, to be processed.
2	NOTE(I)	1-80	20A4	Location and description of the stand, silvicultural system, etc. Stand, as here used, refers to the usual unit area of reasonably uniform site quality, species, stand structure, and age, but subjected to a single combination of management options; i.e., it is the unit for which a yield table is printed.
3	SPEC(I)	1-32	8A4	Species name to be included in the table heading.
	KAK	33-36	I4	Identification number of the tree species in the stand being processed.
	RINT	37-40	F4.0	Number of years for one projection of growth or change. Must never equal zero.
4	ICUT	1-4	I4	To choose: (1) no noncommercial thinnings, (2) initial thinning may be noncommercial, (3) all thinnings may be noncommercial, or (4) no thinnings to be made.
	DSTY	5-8	F4.0	Basal area to be left in thinnings after the first.
	THIN	9-12	F4.0	Basal area to be left after initial thinning.
	THN1	13-16	F4.0	Stand age when first thinning is considered. Must equal AGEO plus a multiple of CYCL.
	CYCL	17-20	F4.0	Number of years between scheduled thinnings. Must be a multiple of RINT.
	COMBF	21-24	F4.0	Minimum cut in board feet for inclusion in merchantable yield printed at bottom of yield table.
	COMCU	25-28	F4.0	Minimum cut in cubic feet for inclusion in merchantable yield printed at bottom of yield table. Also controls the summation of cordwood volumes.
	REGN(1)	29-32	F4.0	Stand age when first regeneration cut is to be made. Must never equal zero. This is the age for clearcutting if rest of the card is blank, and must equal AGEO plus a multiple of RINT.
	VLLV(1)	33-36	F4.1	Basal area in square feet to be left at age REGN(1). Will be zero for clearcutting.
	REGN(2)	37-40	F4.0	Stand age at which second regeneration cut, if any, will occur. Age for removal of seed trees or second cut of shelterwood; must equal AGEO plus a multiple of RINT.
	VLLV(2)	41-44	F4.1	Basal area to be left at age REGN(2). Will be zero except for three-cut shelterwood.
	REGN(3)	45-48	F4.0	Stand age at which third regeneration cut, if any, will occur. Final cut of three-cut shelterwood; must equal AGEO plus a multiple of RINT.
5	STAND	1-4	F4.0	Identification number of the stand.
	SITE	5-8	F4.0	Site index of the stand (base age 50 years) from averages of dominant and codominant trees. Must never equal zero.
	AGEO	9-12	F4.0	Stand age at first entry in the yield table. Present age of an actual stand or any age of a hypothetical stand. Must never equal zero.
	DBHO	13-16	F4.1	Average d.b.h. (inches) of all live trees at stand age AGEO. From average basal area.
	HTSO	17-20	F4.1	Average height (feet) of dominant and codominant trees at age AGEO.
	DENO	21-24	F4.0	Number of live trees in the stand at age AGEO, regardless of crown class. Must never equal zero.

Subroutine PROJ

PROJ performs the following three operations:

1. Projects average d.b.h., height, and number of trees for one growth period and computes the corresponding volumes. Length of the projection period is selected by the program user.
2. Tests to determine if the time of a scheduled thinning or regeneration cut has been reached; if so, transfers program control to subroutine CUTS.
3. Rounds off values for printing and prints one line of the body of the table, if cutting is not scheduled.

Subroutine SWITCH

SWITCH is called by CUTS and PROJ to select sets of species-specific equations and constants to be used in computations. The tree species for which a table is to be computed is identified by the program user. This identification is used in SWITCH to call the group of equations and constants appropriate to the species.

As listed in Appendix 1, SWITCH calls only subroutine LOBPL (species identification number one). Additional calls (i.e., other species relationships) can be substituted, using procedures described in the section on modifications, below.

Subroutine LOBPL

Subroutine LOBPL contains all the equations and constants that apply to loblolly pine plantations. Any one of the 10 sets of statements, described in the next section, is called as needed by other subroutines. A call consists of (1) identification of the type of computation to be made, (2) assignment of values to temporary variables, if necessary, and (3) call to subroutine SWITCH.

PROGRAM RELATIONSHIPS, LOBPL

Nine types of information are computed by the 10 sets of FORTRAN statements in subroutine LOBPL. These sets, numbered in the order in which they appear in LOBPL, are described below.

Set 1--Periodic Increase in Basal Area and Average Stand D.b.h.

An equation derived by Clutter (1963) estimates potential basal area at the end of each projection period. This equation, based on data from natural stands, was used because similar equations for plantations are not yet available. The future number of trees per acre is computed by applying expected mortality percent (Statement 100, 102, LOBPL, Appendix 1) to present number of trees. Dividing projected basal area by projected number of trees provides estimated mean d.b.h.

Set 2 and 8--Initial Average Dominant and Codominant Height and Periodic Increases in Height

An equation by Lenhart (1972) is used to estimate heights at ages under 25, and one by Farrar (1973) for older stands (Statements 20, 21, 22, LOBPL, Appendix 1). Lenhart's equation was modified slightly to permit use of site indexes with a base age of 50 years. Farrar's equation is a mathematical expression of values originally published in Miscellaneous Publication 50 (U.S. Dep. Agric. 1976). This combination better simulated actual plot performance than either equation alone.

Set 3--Initial Basal Area and D.b.h. of Very Young Stands

These values, needed only when simulation begins with a new plantation of 1-foot-tall trees, are based on data from Smalley and Bailey (1974). D.b.h. and basal area are first computed when the stand reaches a height of 4.5 feet and diameter measurements at breast height are possible (Statement 30, LOBPL, Appendix 1).

Set 4--Cubic- and Board-Foot Volumes Per Acre

Cubic-foot volume inside bark is computed from the tree of average diameter, average dominant and codominant height d the number of trees per acre (State- ent 40, LOBPL, Appendix 1). Cubic-foot lume includes all trees 5 inches in d.b.h. d larger to a 4-inch top diameter outside rk. Volumes for the stand equation were tained by summation of tree volumes om an equation by Hasness and Lenhart 972). Similar results were obtained with e Forest Service's tree volume equation r national forests in the west Gulf.

Volumes in rough cords per acre are tained by dividing each cubic volume by .3 (Mesavage 1947).

Cubic volumes are converted to board et Scribner Rule (Statement 43, LOBPL, ppendix 1) for all trees 9 inches in d.b.h. d larger to a 7-inch top diameter inside rk. Board-foot volumes used to compute e conversion factors were obtained with uations for the national forests in Texas.

Because merchantable volumes esti- ated for stands of small average d.b.h. e unreliable, cubic volumes are not com- uted by YLDTBL if average d.b.h. is less an 5.0 inches. Minimum average stand b.h. is 6.0 inches for board-foot volumes. noring the small merchantable volume esent in stands of smaller d.b.h. has little fect on yields, as volumes per acre would less than the minimum for commercial its.

et 5--Change in Average D.b.h. and eight due to Initial Thinning

Initial thinnings may increase or de- rease average residual diameter by re- oving trees that are larger or smaller han average. Changes estimated by sub- routine LOBPL (Statements 50, 51, LOBPL, ppendix 1) are based on available data from actual thinnings. The program esti- ates decreases in average d.b.h. ranging from 0.5 inch for very heavy thinnings to zero where 40 percent of the stand is removed, and increases of 0.1 to 0.2 inch for lighter cuts. Independent data from 59 stands in Louisiana tended to confirm this pattern of changes.

Effect of initial thinning on average height of dominant and codominant trees is not well documented. From available data, the program estimates average reductions of 1 foot in height where removal is over 60 percent and 0.5 foot where removal is 45 to 60 percent, an average increase of 0.5 foot where removal is 45 to 10 percent, and no change for lesser cuts (Statements 52, 53, LOBPL, Appendix 1). Modification of Statements 50, 51, 52, or 53 is advised if local practice results in different changes.

Sets 6 and 7--Change in Average D.b.h. and Height from Partial Cuttings after the First

Based on the observation that most partial cuts after the first remove trees that are on the average smaller than those that are retained, the program estimates that such cuts will increase both average diameters and average heights. Subroutine LOBPL (Statements 60, 61, 62, Appendix 1) estimates diameter increases ranging from about 1.5 inches where only 20 percent of the basal area is retained to near zero where less than 1 percent is cut. Similarly, Statements 63, 64, 65 estimate height increases after cutting, ranging from 1 foot where 45 percent or less of the basal area is retained to zero for cuts retaining 91 percent or more. For cuts retaining between 45 and 91 percent, an increase of 0.5 foot is predicted. Where these relationships are not applicable, the subroutine should be modified to better simulate local practice.

Set 9--Theoretical Initial Number of Trees per Acre

Mortality in unthinned stands is estimated with an equation that includes initial planting density. Set 9 uses a modification of that equation to estimate initial number of trees as a basis for mortality projections in plantations already more than 1 year old (Statement 90, LOBPL, Appendix 1). If stand age at the beginning of simulation is 1 year, actual or assumed initial density is necessary for mortality computations.

Set 10—Change in Number of Trees per Acre Because of Noncatastrophic Mortality

Mortality in unthinned stands is estimated (Statement 100, LOBPL, Appendix 1) with an equation by Smalley and Bailey (1974). Future number of trees in thinned stands is obtained from an equation based on 288 observations in previously-thinned plantations (Statement 102, LOBPL, Appendix 1). These estimates cover the gradual reductions in numbers of trees from competition and endemic insects and diseases. Effects of forest fires, epidemics, and other abrupt changes are not computed by program YLDTBL.

Suitability of the equations and constants in LOBPL were tested by comparing actual and computed performance of 59 plots in Louisiana.[1] Stand values at age 25 were used as initial conditions in the computer runs. Differences between actual and computed values at age 45 were expressed as percentages of actual values. Eighty percent of the computed numbers of trees were within ± 10 percent of actual numbers. Ninety-five percent of the computed average diameters and 76 percent of the cubic volumes per acre were also within 10 percent of actual. Ninety-seven percent of the computed basal areas and 93 percent of average stand heights were within ± 5 percent of actual values.

USER-SUPPLIED INFORMATION

Persons using program YLDTBL must supply values for 23 variables that describe stand conditions, control program execution, and specify management options. Variable names, input formats, and data card sequence are given in table 1. Each variable is also defined there and in the program (Appendix 1). Several of these variables are discussed further in this section.

Data cards are identified by type numbers that, with one exception, show their sequence in the data deck. A type 1 card is required for each computer run. This card is followed by as many sets of four cards of types 2 to 5 as there are yield tables to be computed. For example, a data deck to produce two yield tables will have data cards in the sequence: 1, 2, 3, 4, 5, 2, 3, 4, 5.

Intermediate Cuts

The first seven variables on data card type 4 control execution of intermediate cuts. Certain precautions must be observed when selecting values for these variables.

Each of the four thinning controls (DSTY, THIN, THN1, CYCL) must be assigned a value greater than zero if ICUT is given a value of 1, 2, or 3. Fields for the four controls may be left blank if ICUT has a value of 4.

Stand age at initial thinning, THN1, must equal the initial age, AGEO, plus a multiple of the projection period, RINT, and the interval between intermediate cuts, CYCL, must also be a multiple of RINT. For example, if AGEO is 15 and RINT equals 5, THN1 may be assigned a value of 15, 20, 25, etc., and CYCL can have values of 5, 10, etc.

Minimum commercial volumes, COMBF and COMCU, determine whether or not scheduled thinning will yield a commercia cut. Noncommercial thinnings will not b made if the value given ICUT prevents th action. Volumes removed in permitte noncommercial thinnings are not include in column totals, but projected growth wil reflect the effect of such thinnings. footnote printed at the bottom of eac yield table is a reminder of the user decision.

Regeneration Cuts

The last five entries on data card type determine the regeneration method to b simulated. Stand age when each cut will b made and the basal area of seed trees shelterwood, if any, are specified. Stan ages at regeneration cuts must equal th sum of AGEO plus appropriate multiples the value of RINT.

For clearcutting, stand age at time final cutting, REGN(1), is entered on ca type 4, and the other four regeneratic variables are left blank or given values zero.

---

[1] Feduccia, D. P. 1974. Thinning in a loblolly spacing plantation. Progress report on file at Southern Forest Experiment Station, Pineville, La.

Seed-tree cutting requires non-zero vales for REGN(1), VLLV(1), and REGN(2). EGN(1) is the stand age at first regenertion cutting, and REGN(2) is stand age hen the seed trees are removed. VLLV(1) the basal area to be left as seed trees at ge REGN(1).

Shelterwood cuttings are controlled in ne same manner as seed-tree cuts. The rogram simulates up to three regeneration uts. Two-cut shelterwood requires that alues be assigned to the same three ariables as for the seed-tree method. asal area to be left as a shelterwood is pecified by VLLV(1). For three-cut shelerwood, REGN(1) and REGN(2) are stand ges at time of the removal cuts, and EGN(3) is stand age at the final cut. LLV(1) is the basal area left at age EGN(1), and VLLV(2) is the basal area left t REGN(2).

itial Stand Measurements

Initial stand information is entered on ard type 5, columns 5 through 24. Where erformance of an actual stand is to be rojected, inventory data must be supplied or all five stand variables. Projections for ypothetical stands of any age may be ade if reasonable estimates of the variaes are supplied; if no initial height is ntered, a height appropriate to the site dex will be computed. New plantations hould be assigned an age of 1 year, a eight of 1 foot, and an appropriate number f trees per acre.

Yield tables for hypothetical stands can e used to select rotation lengths, thinning gimes, and other controls on silvicultural perations. Yield tables for actual stands rovide information on expected yields for e remainder of the rotation.

Stand age, AGEO, and average height, TSO, describe dominant and codominant ees only. Stand age includes any growing riod in nursery beds.

PROGRAM MODIFICATIONS

Program YLDTBL can be modified to nulate a variety of conditions not coved by the version in Appendix 1. It can be adapted to compute yield tables for other species or for improved genetic strains of loblolly pine. Estimates of potential yields may be needed in metric units or for other standards of utilization. Whatever the reason, YLDTBL is organized to make modification a relatively easy operation.

Complete modification of the program, as for another species, requires two changes. A new subroutine equivalent to LOBPL is added to the program. One of the CONTINUE cards in subroutine SWITCH is then replaced by a statement calling the new subroutine. No other changes are needed in the program if the new subroutine duplicates the sequence of operations of subroutine LOBPL exactly. The species identification number punched on data card type 3 will be the label of the new statement in subroutine SWITCH. Addition of more than nine subroutines to the program will require replacement of the GO TO statement in SWITCH.

Individual statements in subroutine LOBPL can be replaced to convert to other utilization standards, to introduce new growth and mortality equations, or to describe natural stands. No other changes in the program will be needed, unless the equations contain independent variables not already computed.

YLDTBL can be converted readily to increase reserve basal area as tree height increases, as is current practice in the Forest Service's Southern Region. A series of statements of the form "IF(HTSO .LE. 45.0) THIN = 70.0" is placed at the beginning of Subroutine CUTS to produce this modification. The series is followed by the statement "DSTY = THIN."

AN EXAMPLE

Appendix 2 affords an example of many computations performed by YLDTBL and some of the management alternatives that can be simulated. It may be used as a test problem for adapting YLDTBL to other computing systems.

Assume a forest composed of loblolly pine plantations of various ages. Some of the many questions of interest to the forest manager are:

1. With a specified initial density and no thinning during a 30-year rotation, what volume of cordwood will be produced, and how much of this will be marketable as sawlogs?
2. What will be the volume production for the remainder of the rotation of the stands that were inventoried recently?
3. For a given initial spacing, rotation, and regeneration method, what volumes of sawtimber will be produced with various thinning schedules?

Only three of the many yield tables that would be computed to answer these questions are reproduced in Appendix 2. Species, minimum commercial volumes, site index, and projection interval are the same for all tables, as shown. Regeneration by clearcutting and planting and by two-cut shelterwood are simulated. Other information supplied by the manager appears in the heading, footnotes, and age column of each table.

The data deck consists of 13 cards punched as shown in figure 1. The first card (line 1, containing a single digit) is the type 1 card read by the main program. The next four cards are the type 2, 3, 4, and 5 cards needed to produce the first table. The remaining eight cards are the type 2, 3, 4, and 5 cards for the other two tables.

Each table provides a partial answer to the manager's questions. The table for stand 101 shows potential yields for rotation lengths of 15 to 30 years. Longer rotations could have been included by giving REGN(1) a value larger than 30.

The table for stand 81, now 20 years old, shows estimated yields from an existing stand, if thinned at 5-year intervals. Rotations of 20 to 50 years, terminated by clearcutting and planting, may be compared. Additional yield tables can be obtained to evaluate other thinning and regeneration alternatives.

The third table for stand 102 shows the potential of a silvicultural system involving thinnings at 10-year intervals and regeneration by a two-cut shelterwood. The removal cut is made at age 60, and the final cut is made at age 65.

Tables for other thinning programs are needed to fully evaluate thinning alternatives. They cost about five cents each, once the program has been compiled into machine language.

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Farrar, R. M., Jr.
1973. Southern pine site index equations. J. For. 71: 696-697.

```
   3
HYPOTHETICAL STAND TO EXAMINE CLEARCUTTING WITH SHORT ROTATION,
 LOBLOLLY PINE PLANTATION,          1   5
   4                 1000 229  30
 101  85   1   0   101210
SWAMPY COMPARTMENT OF THE PINEY WOODS TRACT, INVENTORIED 1976,
 LOBLOLLY PINE PLANTATION,          1   5
   2  68  68  20    51000 229  50
  81  85  20   72 500 490
HYPOTHETICAL STAND TO EXAMINE SAWLOG ROTATION AND SHELTERWOOD,
 LOBLOLLY PINE PLANTATION,          1   5
   1 100 110  20   101000 229  60 300  65
 102  85   1   0   101000
```

Figure 1.—Data deck for the sample problem.

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APPENDIX 1

Listing of Program YLDTBL

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    PROGRAM YLDTBL

TO COMPUTE AND PRINT YIELD TABLES FOR EVEN-AGED STANDS.
PROGRAM BY CLIFFORD A. MYERS, SOUTHERN FOREST EXP. STN., 1976.

DEFINITIONS OF VARIABLES.

    ADDHT = CHANGE IN AVERAGE STAND HEIGHT BY THINNING.
    AGEO = AGES REPORTED IN YIELD TABLE.
    BASO = BASAL AREA BEFORE PARTIAL CUT.
    BAST = BASAL AREA AFTER PARTIAL CUT.
    BDFC = BOARD FEET REMOVED PER ACRE.
    BDFO = BOARD FEET BEFORE PARTIAL CUT.
    BDFT = BOARD FEET AFTER PARTIAL CUT.
    CFMC = MERCH. CU. FT. REMOVED PER ACRE.
    CFMO = MERCH. CU. FT. BEFORE PARTIAL CUT.
    CFMT = MERCH. CU. FT. AFTER PARTIAL CUT.
    CHD = CHANGE IN AVE. STAND D.B.H. FROM PARTIAL CUTTING.
    COMBF = MINIMUM COMMERCIAL CUT, BOARD FEET.
    COMCU = MINIMUM COMMERCIAL CUT, CU. FT.
    CRDC = NUMBER OF CORDS REMOVED.
    CRDO = NUMBER OF CORDS BEFORE PARTIAL CUT.
    CRDT = NUMBER OF CORDS AFTER PARTIAL CUT.
    CYCL = INTERVAL BETWEEN INTERMEDIATE CUTS.
    DBHO = AVERAGE STAND D.B.H. BEFORE PARTIAL CUT.
    DBHT = AVERAGE STAND D.B.H. AFTER PARTIAL CUT.
    DENO = TREES PER ACRE BEFORE PARTIAL CUT.
    DENT = TREES PER ACRE AFTER PARTIAL CUT.
    DSTY = RESIDUAL BASAL AREA FOR PARTIAL CUTS AFTER THE FIRST.
    HTSO = AVE. DOM AND CODOM TREE HEIGHT BEFORE CUT.
    HTST = AVE. DOM AND CODOM TREE HEIGHT AFTER CUT.
    ICUT = FLAG WITH INPUT VALUE TO CONTROL THINNINGS OF--
         1 = NO NONCOMMERCIAL THINNINGS.
         2 = INITIAL THINNING MAY BE NONCOMMERCIAL.
         3 = ALL THINNINGS MAY BE NONCOMMERCIAL.
         4 = NO THINNINGS TO BE MADE.
    JSBD = TOTAL BD. FT. FROM ALL CUTS OF COMBF OR LARGER.
    JSMC = TOTAL MERCH. CU. FT. FROM CUTS OF COMCU OR LARGER.
    KAK = SPECIES NUMBER TO SELECT SET OF SPECIES-SPECIFIC STATEMENTS.
    MAC = NUMBER TO SELECT APPROPRIATE OPERATION.
    NOTE(I) = DESCRIPTION TO BE WRITTEN IN YIELD TABLE.
    NSTND = NUMBER OF STANDS TO BE PROCESSED BY THE RUN.
    PRET = PERCENTAGE OF BASAL AREA RETAINED AFTER PARTIAL CUT.
    PROD = FACTOR TO CONVERT MERCH. CU. FT. TO BOARD FEET.
    REGN(I) = STAND AGE WHEN REGENERATION CUT I OCCURS.
    RINT = NUMBER OF YEARS FOR WHICH A SINGLE PROJECTION IS MADE.
    ROTA = FINAL AGE IN YIELD TABLE.
    SCRD = TOTAL YIELD IN CORDS FROM COMMERCIAL CUTS.
    SITE = SITE INDEX.
    SPEC(I) = SPECIES NAME FOR TABLE HEADING.
    STND = STAND IDENTIFICATION NUMBER.
    STRT = INITIAL TREES PER ACRE FOR MORTALITY COMPUTATIONS.
    THIN = RESIDUAL BASAL AREA FOR INITIAL THINNING.
    THN1 = AGE OF STAND WHEN FIRST THINNED.
    VAR(I) = ARRAY FOR STORAGE OF INITIAL VALUES OF VARIABLES.
    VLLV(I) = BASAL AREA TO BE LEFT AT REGN(I).

    COMMON /BLKA/ AGEO,BASO,BAST,BDFO,CFMO,CRDO,CYCL,DBHO,DBHT,DENO,
   1DENT,HTSO,HTST,KAK,MAC,REGN(3),RINT,ROTA,THN1,STRT,KTI
```

```
C
      COMMON /BLKB/ BDFT,CFMT,COMBF,COMCU,CRDT,ICUT,JBDFO,JCFMO,JDENT,
     1JSBD,JSMC,SCRD,STND,VAR(5)
C
      COMMON /BLKC/ ADDHT,CHD,DSTY,PRET,SITE,THIN,VLLV(3)
C
      COMMON /BLKD/ BA,BDF,CFM,CRD,DBH,DEN,HT,IMX,KBL
C
C READ NUMBER OF STANDS TO BE PROCESSED FROM CARD TYPE ONE.
C
      READ (5,20) NSTND
   20 FORMAT (I4)
      IF(NSTND .LE. 0)  GO TO 230
C
C EXECUTE PROGRAM ONCE FOR EACH STAND.
C
      DO 200 I=1,NSTND
      CALL BEGIN
C
C CHECK FOR UNWANTED ZEROS OR BLANKS IN DATA.
C
      DO 30 L=1,5
      IF(VAR(L) .LE. 0.0) GO TO 190
   30 CONTINUE
C
C DETERMINE OLDEST AGE TO BE REPORTED IN TABLE.
C
      DO 40 NA=1,3
      L = 4 - NA
      IF(REGN(L) .EQ. 0.0) GO TO 40
      ROTA = REGN(L)
      GO TO 50
   40 CONTINUE
   50 BASO = DENO * 0.0054542 * DBHO * DBHO
C
C COMPUTE VOLUMES PER ACRE.
C
      MAC = 4
      BA = BASO
      DBH = DBHO
      DEN = DENO
      HT = HTSO
      CALL SWITCH
      BDFO = BDF
      CFMO = CFM
      CRDO = CRD
C
C ENTER LOOP FOR REMAINING COMPUTATIONS AND PRINTOUT.
C
      KAN = (ROTA - AGEO) / RINT + 1.5
      IF (AGEO .EQ. 1.0) KAN = KAN + 1
      DO 100 K=1,KAN
      IF(AGEO .GE. ROTA) GO TO 105
   80 CALL CUTS
      IF(IMX .GT. 0) GO TO 90
      CALL TABLE
   90 CALL PROJ
      IF(KBL .GT. 0) GO TO 80
```

```
  100 CONTINUE
C
C ADD FINAL CUTS TO TOTAL YIELDS AND WRITE TOTAL YIELDS.
C
  105 CFMO = JCFMO
      IF(CFMO .LT. COMCU) GO TO 110
      JSMC = JSMC + JCFMO
      SCRD = SCRD + CRDO
  110 BDFO = JBDFO
      IF(BDFO .LT. COMBF) GO TO 120
      JSBD = JSBD + JBDFO
  120 WRITE (6,130) JSMC,SCRD,JSBD
  130 FORMAT (1H0,/,65X,12HTOTAL YIELDS,23X,I6,4X,F6.1,3X,I7)
C
C WRITE FOOTNOTES TO YIELD TABLE.
C
      WRITE (6,140)
  140 FORMAT (1H0,//,11X,89HCORD AND BOARD-FOOT VOLUME INCLUDED IN CUBIC
     1 VOLUME, BOARD-FOOT VOLUME INCLUDED IN CORDS.)
      WRITE (6,150) COMCU,COMBF
  150 FORMAT (1H ,10X,44HMINIMUM CUTS FOR INCLUSION IN TOTAL YIELDS--,F6
     1.0,15H CUBIC FEET AND,F7.0,12H BOARD FEET.)
      GO TO (160,165,170,175), ICUT
  160 WRITE(6,163)
  163 FORMAT (1H ,10X,35HNO NONCOMMERCIAL THINNINGS ALLOWED.)
      GO TO 200
  165 WRITE (6,168)
  168 FORMAT (1H ,10X,43HONLY INITIAL THINNING MAY BE NONCOMMERCIAL.)
      GO TO 200
  170 WRITE (6,173)
  173 FORMAT (1H ,10X,35HALL THINNINGS MAY BE NONCOMMERCIAL.)
      GO TO 200
  175 WRITE (6,178)
  178 FORMAT (1H ,10X,39HNO THINNINGS SCHEDULED DURING ROTATION.)
      GO TO 200
C
C PROGRAM CONTROL GOES HERE IF ANY UNWANTED ZEROS OR BLANKS IN DATA.
C
  190 WRITE (6,195) STND
  195 FORMAT (1H0,///,10X,73HEXECUTION STOPPED BECAUSE OF NEGATIVE OR ZE
     1RO ITEM ON DATA CARDS OF STAND,F6.0)
  200 CONTINUE
      GO TO 250
C
C PROGRAM CONTROL GOES HERE IF NSTND ILLEGAL.
C
  230 WRITE (6,240)
  240 FORMAT (1H1,////,30X,52HEXECUTION STOPPED BECAUSE OF ILLEGAL VALUE
     1 OF NSTND.)
  250 STOP
      END
      SUBROUTINE BEGIN
C
C TO INITIALIZE VARIABLES AND READ IN DATA.
C
      COMMON /BLKA/ AGEO,BASO,BAST,BDFO,CFMO,CRDO,CYCL,DBHO,DBHT,DENO,
     1DENT,HTSO,HTST,KAK,MAC,REGN(3),RINT,ROTA,THN1,STRT,KTI
```

```
      COMMON /BLKB/ BDFT,CFMT,COMBF,COMCU,CRDT,ICUT,JBDFO,JCFMO,JDENT,
     1JSBD,JSMC,SCRD,STND,VAR(5)
C
      COMMON /BLKC/ ADDHT,CHD,DSTY,PRET,SITE,THIN,VLLV(3)
C
      COMMON /BLKD/ BA,BDF,CFM,CRD,DBH,DEN,HT,IMX,KBL
C
      DIMENSION NOTE(20),SPEC(8)
C
      ADDHT = 0.0
      BDFO = 0.0
      BDFT = 0.0
      CFMO = 0.0
      CFMT = 0.0
      CRDO = 0.0
      CRDT = 0.0
      BASO = 0.0
      BAST = 0.0
      IMX = 0
      JSBD = 0
      JSMC = 0
      KTI = 0
      SCRD = 0.0
      STRT = 0.0
      DO 5 I=1,5
    5 VAR(I) = 0.0
      DO 10 I=1,3
      REGN(I) = 0.0
      VLLV(I) = 0.0
   10 CONTINUE
C
C READ TREATMENT DESCRIPTION FROM CARD TYPE TWO.
C
      READ (5,30) (NOTE(I),I=1,20)
   30 FORMAT (20A4)
C
C READ SPECIES IDENTIFICATION FROM CARD TYPE THREE.
C
      READ (5,40) (SPEC(I),I=1,8),KAK,RINT
   40 FORMAT (8A4,I4,F4.0)
C
C READ CUTTING INSTRUCTIONS FROM CARD TYPE FOUR.
C
      READ (5,50) ICUT,DSTY,THIN,THN1,CYCL,COMBF,COMCU,REGN(1),VLLV(1),
     1REGN(2),VLLV(2), REGN(3)
   50 FORMAT (I4,7F4.0,F4.1,F4.0,F4.1,F4.0)
C
C READ INITIAL STAND VALUES FROM CARD TYPE FIVE.
C
      READ (5,60) STND,SITE,AGEO,DBHO,HTSO,DENO
   60 FORMAT (3F4.0,2F4.1,F4.0)
      VAR(1) = AGEO
      VAR(2) = DENO
      VAR(3) = RINT
      VAR(4) = SITE
      VAR(5) = REGN(1)
C
C COMPUTE AVE. DOM AND CODOM HEIGHT IF NOT READ IN.
```

```
C
      IF(HTSO .GT. 0.0) GO TO 70
      MAC = 8
      CALL SWITCH
C
C COMPUTE THEORETICAL INITIAL NUMBER OF TREES.
C
   70 IF(AGEO .EQ. 0.0) GO TO 80
      IF(DENO .EQ. 0.0) GO TO 80
      MAC = 9
      CALL SWITCH

C
C WRITE HEADINGS FOR YIELD TABLE.
C
      JSITE = SITE
   80 WRITE (6,100) STND,SPEC
  100 FORMAT(1H1,//,32X,31HYIELDS PER ACRE OF STAND NUMBER,F7.0,1H,,8A4)
      WRITE (6,110) JSITE,THIN,DSTY
  110 FORMAT (1H0,58X,10HSITE INDEX,I4/1H ,38X,29HRESIDUAL BASAL AREA- I
     1NITIAL-,F6.0,12H SUBSEQUENT-,F6.0)
      WRITE (6,120) (NOTE(J),J=1,20)
  120 FORMAT (1H0,25X,20A4)
      WRITE (6,130)
  130 FORMAT (1H0,/,4X,74H-------------------CHARACTERISTICS OF STANDING
     1 TREES----------------------,4X,45H-------------PERIODIC REDUCTION
     2S-------------)
      WRITE (6,140)
  140 FORMAT (1H0,2X,5HSTAND,13X,5HBASAL,5X,7HAVERAGE,3X,7HAVERAGE,43X,5
     1HBASAL)
      WRITE (6,150)
  150 FORMAT (1H ,3X,3HAGE,5X,5HTREES,4X,4HAREA,7X,6HD.B.H.,3X,6HHEIGHT,
     15X,6HVOLUME,4X,6HVOLUME,4X,6HVOLUME,4X,5HTREES,4X,4HAREA,6X,6HVOLU
     2ME,4X,6HVOLUME,4X,6HVOLUME)
      WRITE (6,160)
  160 FORMAT (1H ,2X,5H(YRS),5X,3HNO.,5X,6HSQ.FT.,6X,3HIN.,7X,3HFT.,6X,
     16HCU.FT.,4X,5HCORDS,5X,6HBD.FT.,5X,3HNO.,5X,6HSQ.FT.,4X,6HCU.FT.,4
     2X,5HCORDS,5X,6HBD.FT.)
C
C ASSIGN VALUES TO PREVENT THINNING IF THINNING NOT WANTED.
C
      IF(ICUT .GT. 0 .AND. ICUT .LT. 4) GO TO 200
      DSTY = 500.0
      THIN = 500.0
      CYCL = REGN(1) - AGEO
      THN1 = REGN(1)
  200 RETURN
      END
      SUBROUTINE CUTS
C
C TO EXECUTE INTERMEDIATE AND REGENERATION CUTS.
C
      COMMON /BLKA/ AGEO,BASO,BAST,BDFO,CFMO,CRDO,CYCL,DBHO,DBHT,DENO,
     1DENT,HTSO,HTST,KAK,MAC,REGN(3),RINT,ROTA,THN1,STRT,KTI
C
      COMMON /BLKB/ BDFT,CFMT,COMBF,COMCU,CRDT,ICUT,JBDFO,JCFMO,JDENT,
     1JSBD,JSMC,SCRD,STND,VAR(5)
C
      COMMON /BLKC/ ADDHT,CHD,DSTY,PRET,SITE,THIN,VLLV(3)
```

```
C
      COMMON /BLKD/ BA,BDF,CFM,CRD,DBH,DEN,HT,IMX,KBL
C
      IF(AGEO .LT. THN1) GO TO 90
C
C EXECUTE SCHEDULED REGENERATION CUTS.
C
      IF(AGEO .GE.ROTA) GO TO 100
      IF(AGEO .LT. REGN(1)) GO TO 30
      IF(AGEO .NE. REGN(1)) GO TO 10
      MAC = 7
      CALL SWITCH
      GO TO 70
   10 IF(AGEO .NE. REGN(2)) GO TO 30

      MAC = 7
      CALL SWITCH
      GO TO 70
C
C CHANGE AVE. D.B.H. AND AVE. HT. BY INTERMEDIATE CUTTING.
C
   30 IF(AGEO .NE. THN1) GO TO 40
   35 PRET = (THIN / BASO) * 100.0
      BAST = THIN
      MAC = 5
      CALL SWITCH
      GO TO 70
   40 DO 50 IK=1,20
      TEM = IK
      TMPY = THN1 + (CYCL * TEM)
      IF(TMPY .GE. REGN(1)) GO TO 90
      IF(AGEO .EQ. TMPY) GO TO 60
   50 CONTINUE
      GO TO 90
   60 IF(KTI .EQ. 0) GO TO 35
      PRET = (DSTY / BASO) * 100.0
      BAST = DSTY
      MAC = 6
      CALL SWITCH
   70 DBHT = DBHO + CHD
      HTST = HTSO + ADDHT
      JDENT = (BAST / (0.0054542 * DBHT * DBHT)) + 0.5
      DENT = JDENT
      BAST = 0.0054542 * DBHT * DBHT * DENT
      IF(BAST .GE. BASO) GO TO 90
      MAC = 4
      BA = BAST
      DBH = DBHT
      DEN = DENT
      HT = HTST
      CALL SWITCH
      BDFT = BDF
      CFMT = CFM
      CRDT = CRD
C
C DO NOT EXECUTE THINNING IF FORBIDDEN BY STANDARDS.
C
      TEM = CFMO - CFMT
      IF(TEM .GE. COMCU) GO TO 100
      IF(ICUT .EQ. 3) GO TO 100
      IF(AGEO .EQ. THN1 .AND. ICUT .EQ. 2) GO TO 100
   90 BAST = BASO
      HTST = HTSO
      DENT = DENO
      JDENT = DENO + 0.5
      DBHT = DBHO
      CRDT = CRDO
      BDFT = BDFO
      CFMT = CFMO
      IF(AGEO .EQ. THN1) KTI = 0
  100 RETURN
      END
      SUBROUTINE TABLE
C
C TO PRINT RESULTS OF PROJECTIONS AND CUTS.
C
      COMMON /BLKA/ AGEO,BASO,BAST,BDFO,CFMO,CRDO,CYCL,DBHO,DBHT,DENO,
     1DENT,HTSO,HTST,KAK,MAC,REGN(3),RINT,ROTA,THN1,STRT,KTI
C
      COMMON /BLKB/ BDFT,CFMT,COMBF,COMCU,CRDT,ICUT,JBDFO,JCFMO,JDENT,
     1JSBD,JSMC,SCRD,STND,VAR(5)
C
C ROUND OFF VALUES FOR PRINTING.
C
      JAGEO = AGEO
      JDENO = DENO + 0.5
      JHTSO = HTSO + 0.5
      JBASO = BASO + 0.5
      JCFMO = (CFMO * 0.1) + 0.5
      JCFMO = JCFMO * 10
      JBDFO = (BDFO * 0.01) + 0.5
      JBDFO = JBDFO * 100
      IF(DENT .EQ. DENO) GO TO 20
      JHTST = HTST + 0.5
      JCFMT = (CFMT * 0.1) + 0.5
      JCFMT = JCFMT * 10
      IF(JCFMT .GT. JCFMO) JCFMO = JCFMT
      IF(CRDT .GT. CRDO) CRDO = CRDT
      JBDFT = (BDFT * 0.01) + 0.5
      JBDFT = JBDFT * 100
      IF(JBDFT .GT. JBDFO) JBDFO = JBDFT
      JBAST = BAST + 0.5
      JDENC = JDENO - JDENT
      JBASC = JBASO - JBAST
      CRDC = CRDO - CRDT
      JCFMC = JCFMO - JCFMT
      IF(JCFMC .LE. 0) JCFMC = 0
      JBDFC = JBDFO - JBDFT
      IF(JBDFC .LE. 0) JBDFC = 0
C
C SUM PERIODIC CUTS FOR LAST LINE OF YIELD TABLE.
C
      IF(AGEO .GE. ROTA) GO TO 20
      CFMC = JCFMC
      IF(CFMC .LT. COMCU) GO TO 10
      SCRD = SCRD + CRDC
      JSMC = JSMC + JCFMC
   10 BDFC = JBDFC
      IF(BDFC .LT. COMBF) GO TO 20
      JSBD = JSBD + JBDFC
C
C WRITE TABLE ENTRIES OF DIAMETER, VOLUMES, ETC.
C
   20 WRITE (6,30) JAGEO,JDENO,JBASO,DBHO,JHTSO,JCFMO,CRDO,JBDFO
   30 FORMAT (1H0,2X,I4,5X,I5,4X,I4,7X,F5.1,5X,I3,7X,I5,5X,F5.1,4X,I6)
      IF(AGEO .GE. ROTA) GO TO 60
      IF(DENT .EQ. DENO) GO TO 60
      WRITE (6,40) JAGEO,JDENT,JBAST,DBHT,JHTST,JCFMT,CRDT,JBDFT,JDENC,
     1JBASC,JCFMC,CRDC,JBDFC
   40 FORMAT (1H ,2X,I4,5X,I5,4X,I4,7X,F5.1,5X,I3,7X,I5,5X,F5.1,4X,I6,4X
     1,I5,5X,I4,6X,I5,5X,F5.1,4X,I6)
   60 RETURN
      END
      SUBROUTINE PROJ
C
C TO CHANGE STAND CHARACTERISTICS THROUGH GROWTH AND MORTALITY.
C
      COMMON /BLKA/ AGEO,BASO,BAST,BDFO,CFMO,CRDO,CYCL,DBHO,DBHT,DENO,
     1DENT,HTSO,HTST,KAK,MAC,REGN(3),RINT,ROTA,THN1,STRT,KTI
C
      COMMON /BLKD/ BA,BDF,CFM,CRD,DBH,DEN,HT,IMX,KBL
C
      IMX = 0
      KBL = 0
      IF(RINT .EQ. 1.0) GO TO 5
      IF(AGEO .EQ. 1.0) AGEO = 0.0
    5 AGEO = AGEO + RINT
      IF(AGEO .GT. ROTA) GO TO 100
C
C PROJECT STAND VALUES FOR ONE PERIOD.
C
      MAC = 2
      CALL SWITCH
      MAC = 10
      CALL SWITCH
      IF(HTSO .GE. 4.5 .AND. BASO .EQ. 0.0) GO TO 10
      GO TO 20
   10 MAC = 3
      CALL SWITCH
      GO TO 25
   20 MAC = 1
      CALL SWITCH
   25 MAC = 4
      BA = BASO
      DBH = DBHO
      DEN = DENO
      HT = HTSO
      CALL SWITCH
      BDFO = BDF
      CFMO = CFM
      CRDO = CRD
C
C TEST FOR INTERMEDIATE OR REGENERATION CUT.
C
      DO 30 KU=1,3
      IF(AGEO .EQ. REGN(KU)) GO TO 60
   30 CONTINUE
      IF(AGEO .EQ. THN1) GO TO 60
      DO 40 IK=1,20
      TEM = IK
      TMPY = THN1 + (CYCL * TEM)
      IF(TMPY .GE. REGN(1)) GO TO 70
      IF(AGEO .EQ. TMPY) GO TO 60
   40 CONTINUE
      GO TO 70
   60 KBL = 1
      GO TO 100
C
C CHANGE MODE AND ROUND OFF FOR PRINTING.
C
   70 KDENO = DENO + 0.5
      KAGEO = AGEO
      KHTSO = HTSO + 0.5
      KBASO = BASO + 0.5
      KCFMO = (CFMO * 0.1) + 0.5
      KCFMO = KCFMO * 10
      KBDFO = (BDFO * 0.01) + 0.5
      KBDFO = KBDFO * 100

C
C WRITE VALUES FOR THE PERIOD IF CUTTING NOT SCHEDULED.
C
      WRITE (6,80) KAGEO,KDENO,KBASO,DBHO,KHTSO,KCFMO,CRDO,KBDFO
   80 FORMAT (1H0,2X,I4,5X,I5,4X,I4,7X,F5.1,5X,I3,7X,I5,5X,F5.1,4X,I6)
      BAST = BASO
      DBHT = DBHO
      DENT = DENO
      HTST = HTSO
      IMX = 1
  100 RETURN
      END
      SUBROUTINE SWITCH
C
C TO CALL SUBROUTINES WITH SPECIES-SPECIFIC STATEMENTS.
C
      COMMON /BLKA/ AGEO,BASO,BAST,BDFO,CFMO,CRDO,CYCL,DBHO,DBHT,DENO,
     1DENT,HTSO,HTST,KAK,MAC,REGN(3),RINT,ROTA,THN1,STRT,KTI
C
      COMMON /BLKC/ ADDHT,CHD,DSTY,PRET,SITE,THIN,VLLV(3)
C
      COMMON /BLKD/ BA,BDF,CFM,CRD,DBH,DEN,HT,IMX,KBL
C
      GO TO (1,2,3,4,5,6,7,8,9,10),KAK
C
C REPLACE CONTINUES WITH CALLS FOR OTHER SPECIES OR CONDITIONS.
C
    1 CALL LOBPL
      RETURN
    2 CONTINUE
      RETURN
    3 CONTINUE
      RETURN
    4 CONTINUE
      RETURN
    5 CONTINUE
      RETURN
    6 CONTINUE
      RETURN
    7 CONTINUE
      RETURN
    8 CONTINUE
      RETURN
    9 CONTINUE
      RETURN
   10 CONTINUE
      RETURN
      END
      SUBROUTINE LOBPL
C
C SPECIES-SPECIFIC STATEMENTS FOR LOBLOLLY PINE PLANTATIONS.
C
      COMMON /BLKA/ AGEO,BASO,BAST,BDFO,CFMO,CPDO,CYCL,DBHO,DBHT,DENO,
     1DENT,HTSO,HTST,KAK,MAC,REGN(3),RINT,ROTA,THN1,STRT,KTI
C
      COMMON /BLKC/ ADDHT,CHD,DSTY,PRET,SITE,THIN,VLLV(3)
C
      COMMON /BLKD/ BA,BDF,CFM,CRD,DBH,DEN,HT,IMX,KBL
C
      DIMENSION TMH(2)
      GO TO (10,20,30,40,50,60,70,80,90,100), MAC

C
C COMPUTE D.B.H. AT END OF PERIOD.
C COMPUTE BASAL AREA USING AN EQUATION FROM CLUTTER (1963).
C
   10 AA = (AGEO - RINT) / AGEO
      BB = 1.0 - AA
      IF(BAST .EQ. 0.0) GO TO 11
      SQFT = EXP(AA*ALOG(BAST)+4.6012 * BB + 0.013597 * BB * SITE)
      GROB = SQFT - BAST
      BOLE = DBHO - 3.0
      IF(DBHO .LT. 4.0) BOLE = DBHO
      BMORT = 0.0054542 * BOLE * BOLE * DIE
      BASO = BAST + GROB - BMORT
      DBHO = BASO / (0.0054542 * DENO)
      DBHO = SQRT(DBHO)
   11 RETURN
C
C COMPUTE AVE. DOM AND CODOM HEIGHT USING EQUATIONS FROM LENHART (1972)
C MODIFIED AND FROM FARRAR (1973).
C
   20 BO = AGEO
      DO 24 K=1,2
      IF(K .EQ. 2) BO = AGEO - RINT
      IF(BO .LE. 0.0) BO = 1.0
      IF(BO .LT. 3.0) GO TO 21
      IF(BO .GE. 25.0) GO TO 22
      TMH(K) = ALOG10(SITE * 0.65) + 0.1489 - 3.72183 / BO
      TMH(K) = 10.0 ** TMH(K)
      GO TO 24
   21 TMH(K) = 1.4 * BO
      GO TO 24
   22 TEM = BO * BO
```

```
      TMH(K) = ALOG10(SITE) - 2.41737 / B0 - 273.824 / TEM + 4227.7 /
     1 (B0 * TEM) - 19758.5 / (TEM * TEM) + 0.1272
      TMH(K) = 10.0 ** TMH(K)
   24 CONTINUE
      HTSO = HTST + (TMH(1) - TMH(2))
      RETURN
C
C COMPUTE INITIAL D.B.H. OF VERY YOUNG STANDS.
C BASED ON INITIAL ENTRIES IN TABLES OF SMALLEY AND BAILEY (1974).
C
   30 TEM = 0.0
      IF(AGEO .LE. 3.0) GO TO 33
      TEM = 0.10451 - 0.04765 * ALOG10(STRT) + 0.00707 * SITE - 0.00166
     1 * ALOG10(STRT) * SITE
      TEM = TEM * 0.142857 * (AGEO - 3.0)
      BASO = DENO * TEM
      DBHO = BASO / (0.0054542 * DENO)
      DBHO = SQRT(DBHO)
   33 RETURN
C
C COMPUTE VOLUMES PER ACRE IN DESIRED UNITS.
C
   40 BDF = 0.0
      CFM = 0.0
      CRD = 0.0
      PROD = 0.0
      IF(DBH .LT. 5.0) GO TO 45
      D2H = DBH * DBH * HT
C
C MERCH. CU. FT. I.B. IN TREES 5 INCHES D.B.H. AND LARGER TO 4-INCH TOP
C D.O.B.
C N=280.  R=0.999  SEE=0.2274 OR 2.8 PCT OF MEAN.
C
      CFM = (0.00196 * D2H - 0.00229 * BA - 0.63813) * DEN
      CRD = CFM / 76.3
C
C BD. FT. SCRIBNER IN TREES 9 INCHES D.B.H. AND LARGER TO 7-INCH TOP
C D.I.B.
C N=143.  R=0.991  SEE=0.2125 OR 6.5 PCT OF MEAN.
C N=21.  R=0.929  SEE=0.09984 OR 17.3 PCT OF MEAN.
C
      IF(DBH .LT. 6.0) GO TO 45
      IF(DBH .LT. 7.2) GO TO 41
      PROD = 12.46511 - 0.00643 * DBH * DBH - 78.29543 / DBH
      GO TO 43
   41 PROD = 1.0330 * DBH - 6.1949
   43 BDF = CFM * PROD
   45 RETURN
C
C COMPUTE CHANGE IN AVE. D.B.H. AND HT., INITIAL THINNING.
C N=39.  R=0.788  SEE=0.158 OR 15.8 PCT OF MEAN.
C N=14.  R=0.607  SEE=0.121 OR 9.9 PCT OF MEAN.
C
   50 KTI = 1
      IF(PRET .GT. 74.0) GO TO 51
      CHD = 0.0193 * PRET - 1.1591
      IF(PRET .LT. 40.0) CHD = -0.5
      GO TO 52
   51 CHD = 1.0543 - 0.0106 * PRET
   52 IF(PRET .LT. 65.0) GO TO 53
      ADDHT = 0.5
      IF(PRET .GT. 90.0) ADDHT = 0.0
      GO TO 54
   53 ADDHT = 0.0
      IF(PRET .LT. 55.0) ADDHT = -0.5
      IF(PRET .LT. 40.0) ADDHT = -1.0
   54 RETURN
C
C COMPUTE CHANGE IN AVE. D.B.H. AND HT. DUE TO THINNINGS AFTER THE FIRST
C
   60 IF(PRET .GT. 66.0) GO TO 61
      CHD = 0.90052 - 0.02486 * PRET
      CHD = EXP(CHD)
      GO TO 63
   61 IF(PRET .GT. 90.0) GO TO 62
      CHD = 0.12539 + 0.0157 * PRET - 0.000157 * PRET * PRET
      GO TO 63
   62 CHD = 2.666 - 0.02666 * PRET
   63 IF(PRET .LT. 90.0) GO TO 64
      ADDHT = 0.0
      GO TO 66
   64 IF(PRET .LT. 45.0) GO TO 65
      ADDHT = 0.5
      GO TO 66
   65 ADDHT = 1.0
   66 RETURN
C
C COMPUTE CHANGES IN STAND VARIABLES DUE TO PARTIAL REGENERATION CUTS.
C
   70 IF(AGEO .EQ, REGN(2)) GO TO 73
      BAST = VLLV(1)
      GO TO 75
   73 BAST = VLLV(2)
   75 PRET = (BAST / BASO) * 100.0
      CHD = 0.90052 - 0.02486 * PRET
      CHD = EXP(CHD)
      DBHT = DBHO + CHD
      DENT = BAST / (0.0054542 * DBHT * DBHT)
      ADDHT = 0.0
      RETURN
C
C COMPUTE INITIAL HEIGHT IF NOT READ IN.
C
   80 IF(AGEO .LT. 3.0) GO TO 81
      IF(AGEO .GE. 25.0) GO TO 82
      HTSO = ALOG10(SITE * 0.65) + 0.1489 - 3.72183 / AGEO
      HTSO = 10.0 ** HTSO
      GO TO 84
   81 HTSO = 1.4 * AGEO
      GO TO 84
   82 TEM = AGEO * AGEO
      HTSO = ALOG10(SITE) - 2.41737 / AGEO - 273.824 / TEM + 4227.7 /
     1 (AGEO * TEM) - 19758.5 / (TEM * TEM) + 0.1272
      HTSO = 10.0 ** HTSO
   84 RETURN
C
```

```
C COMPUTE THEORETICAL INITIAL NUMBER OF TREES FOR MORTALITY EQUATION.
C
   90 RED = ALOG10(DENO)+0.0009*HTSO*AGEO - 0.0109 * SQRT(HTSO) * AGEO
      RED = RED / (1.0 - 0.0130 * AGEO)
      STRT = 10.0 ** RED
      IF(AGEO .EQ. 1.0) STRT = DENO
      RETURN
C
C COMPUTE NUMBER OF TREES PER ACRE WITH NONCATASTROPHIC MORTALITY.
C
  100 DIE = 0.0
      IF(AGEO .GE. THN1 .AND. KTI .GT. 0) GO TO 102
C
C MORTALITY IN UNTHINNED STANDS - SMALLEY AND BAILEY (1974).
C
      RED = AGEO * (0.013 * ALOG10(STRT) + 0.0009 * HTSO - 0.0109 *
     1SQRT(HTSO))
      RED = 10.0 ** RED
      DENO = STRT / RED
      IF(DENO .GT. DENT) DENO = DENT
      DIE = DENT - DENO
      GO TO 105
C
C MORTALITY IN THINNED STANDS.
C FITTED TO D.B.H. CLASS AVERAGES, 83 PCT OF OBSERVATIONS WERE ZERO.
C
  102 RED = 0.0311 - 0.0020 * DBHT
      RED = RED * (RINT / 5.0)
      IF(RED .LT. 0.0) RED = 0.0
      DENO = DENT * (1.0 - RED)
  105 RETURN
      END
```

APPENDIX 2

Output of Sample Problem.

```
                      YIELDS PER ACRE OF STAND NUMBER    81.,  LOBLOLLY PINE PLANTATION.

                                                  SITE INDEX  85
                            RESIDUAL BASAL AREA- INITIAL-   68, SUBSEQUENT-   68.

                    SWAMPY COMPARTMENT OF THE PINEY WOODS TRACT, INVENTORIED 1976.

-----------------CHARACTERISTICS OF STANDING TREES--------------------    ------------PERIODIC REDUCTIONS-----------

STAND                BASAL      AVERAGE   AVERAGE                                              BASAL
 AGE      TREES      AREA       D.B.H.    HEIGHT     VOLUME    VOLUME    VOLUME      TREES     AREA      VOLUME    VOLUME    VOLUME
(YRS)      NO.       SQ.FT.      IN.       FT.       CU.FT.    CORDS     BD.FT.       NO.      SQ.FT.    CU.FT.    CORDS     BD.FT.

 20        490       139          7.2      50         2020      26.5      2500
 20        255        68          7.0      50         1010      13.2      1000        235       71       1010      13.3      1500

 25        251        92          8.2      54         1580      20.7      4000
 25        167        68          8.7      54         1200      15.8      3500         84       24        380       4.9       500

 30        165        88          9.9      63         1850      24.3      7300
 30        117        68         10.3      63         1450      19.0      6100         48       20        400       5.3      1200

 35        116        84         11.6      70         2040      26.8      9900
 35         88        68         11.9      71         1670      21.9      8300         28       16        370       4.8      1600

 40         87        83         13.2      77         2210      29.0     12000
 40         68        68         13.5      77         1830      24.0     10100         19       15        380       5.0      1900

 45         68        81         14.8      82         2320      30.4     13400
 45         55        68         15.1      82         1980      26.0     11500         13       13        340       4.4      1900

 50         55        80         16.3      86         2430      31.8     14500


                                                           TOTAL YIELDS                          5310      69.5     22600


         CORD AND BOARD-FOOT VOLUME INCLUDED IN CUBIC VOLUME, BOARD-FOOT VOLUME INCLUDED IN CORDS.
         MINIMUM CUTS FOR INCLUSION IN TOTAL YIELDS--  229. CUBIC FEET AND  1000. BOARD FEET.
         ONLY INITIAL THINNING MAY BE NONCOMMERCIAL.
```

```
                         YIELDS PER ACRE OF STAND NUMBER   101.,  LOBLOLLY PINE PLANTATION.

                                              SITE INDEX  85
                              RESIDUAL BASAL AREA- INITIAL-    0. SUBSEQUENT-    0.

                      HYPOTHETICAL STAND TO EXAMINE CLEARCUTTING WITH SHORT ROTATION.

 ------------------CHARACTERISTICS OF STANDING TREES----------------------   -------------PERIODIC REDUCTIONS-------------
 STAND               BASAL     AVERAGE   AVERAGE                                            BASAL
  AGE      TREES     AREA      D.B.H.    HEIGHT     VOLUME    VOLUME    VOLUME     TREES    AREA      VOLUME    VOLUME    VOLUME
 (YRS)      NO.      SQ.FT.     IN.        FT.      CU.FT.    CORDS     BD.FT.      NO.     SQ.FT.    CU.FT.    CORDS     BD.FT.

    1      1210        0         .0         1          0        .0         0
    5      1053       37        2.5        14          0        .0         0
   10      1026      107        4.4        33          0        .0         0
   15       939      153        5.5        44       1470      19.3         0
   20       835      180        6.3        50       2380      31.2       700
   25       733      196        7.0        55       3050      40.0      3100
   30       593      200        7.9        63       3890      51.0      8200

                                                         TOTAL YIELDS                         3890      51.0      8200

       CORD AND BOARD-FOOT VOLUME INCLUDED IN CUBIC VOLUME, BOARD-FOOT VOLUME INCLUDED IN CORDS.
       MINIMUM CUTS FOR INCLUSION IN TOTAL YIELDS--  229. CUBIC FEET AND  1000. BOARD FEET.
       NO THINNINGS SCHEDULED DURING ROTATION.
```

```
                                        SITE INDEX  85
                          RESIDUAL BASAL AREA= INITIAL=  110, SUBSEQUENT=  100,

                 HYPOTHETICAL STAND TO EXAMINE SAWLOG ROTATION AND SHELTERWOOD,

------------------CHARACTERISTICS OF STANDING TREES---------------------    -------------PERIODIC REDUCTIONS------------
STAND                BASAL   AVERAGE   AVERAGE                                        BASAL
 AGE      TREES      AREA    D,B,H,    HEIGHT    VOLUME   VOLUME   VOLUME     TREES   AREA     VOLUME   VOLUME   VOLUME
(YRS)      NO,      SQ,FT,    IN,        FT,      CU,FT,   CORDS    BD,FT,     NO,    SQ,FT,    CU,FT,   CORDS    BD,FT,

  1       1000        0        ,0        1          0       ,0        0
  5        881       35       2,7       14          0       ,0        0
 10        869      105       4,7       33          0       ,0        0
 15        805      150       5,9       44       1560     20,5        0
 20        726      178       6,7       50       2450     32,2     1800
 20        444      110       6,7       50       1590     20,9     1200      282      68       860     11,3      600
 25        436      136       7,6       55       2260     29,6     3900
 30        429      156       8,2       63       3130     41,0     7700
 30        244      100       8,7       64       2080     27,3     6200      185      56      1050     13,7     1500
 35        241      118       9,5       71       2780     36,5    10100
 40        238      133      10,1       77       3450     45,2    14100
 40        164      100      10,6       77       2620     34,4    11400       74      33       830     10,8     2700
 45        162      114      11,3       82       3190     41,8    15100
 50        161      126      12,0       86       3720     48,8    18600
 50        120      100      12,3       86       2980     39,1    15400       41      26       740      9,6     3200
 55        119      111      13,1       89       3450     45,2    18500
 60        119      121      13,7       92       3890     51,0    21500
 60         24       29      15,0       92        960     12,5     5500       95      92      2930     38,4    16000
 65         24       35      16,4       94       1180     15,5     7000

                                                           TOTAL YIELDS                        7590     99,3    30400

       CORD AND BOARD-FOOT VOLUME INCLUDED IN CUBIC VOLUME, BOARD-FOOT VOLUME INCLUDED IN CORDS,
       MINIMUM CUTS FOR INCLUSION IN TOTAL YIELDS--  229, CUBIC FEET AND  1000, BOARD FEET,
       NO NONCOMMERCIAL THINNINGS ALLOWED,
```

☆U.S. GOVERNMENT PRINTING OFFICE: 1977—772-996/274

Myers, Clifford A.
1977. A computer program for variable density yield tables for loblolly pine plantations. South. For. Exp. Stn., New Orleans, La. 31 p. (USDA For. Serv. Gen. Tech. Rep. SO-11)

The computer program described here uses relationships developed from research on loblolly pine growth to predict volumes and yields of planted stands, over the site range of the species, under a wide range of management alternatives. Timing and severity of thinnings, length of rotation, and type of harvest can be modified to compare the effects of various management strategies on wood yield. The program can be modified readily for other conditions or species.

Additional keywords: Timber management, forest management, simulation, Pinus taeda.

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Simulating Timber and Deer Food Potential In Loblolly Pine Plantations

CLIFFORD A. MYERS

Southern
Forest
Experiment
Station

SUMMARY

This computer program analyzes both timber and deer food production on managed forests, providing estimates of the number of acres required per deer for each week or month, yearly timber cuts, and current timber growing stock, as well as a cost and return analysis of the timber operation. Input variables include stand descriptors, controls on management, stumpage prices, and costs of various activities and practices. Equations and constants contained in the program estimate the production of various classes of deer food from these timber stand and management parameters. Foods are evaluated in terms of seasonal nutrient content and the metabolic requirements of white-tailed deer. The program is applicable to loblolly pine plantations in east Texas and Louisiana but can be readily modified for other species or areas.

Additional keywords: Timber management, forest management, simulation, deer habitat potential, wildlife foods, deer management, *Pinus taeda, Odocoileus virginianus.*

1977

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Simulating Timber and Deer Food Potential In Loblolly Pine Plantations

CLIFFORD A. MYERS

INTRODUCTION

Southern foresters need to increase prouction of fast-growing pines greatly to eet projected demands for wood products. n obvious way to boost production is to crease the area devoted to pine plantaions and to intensify their management. uch practices, of course, will affect food nd cover for wildlife, including whiteiled deer (*Odocoileus virginianus* L.). herefore, land managers will need to valuate potential changes in deer habitat efore deciding on a silvicultural plan for a articular area. If deer are to be mainined on the area, silvicultural prescripons that benefit the deer herd without nacceptable effects on costs or timber elds should be a major goal.

Simulation on digital computers provides means of examining the probable outome of several courses of action without pending all the time and money otherise needed for field trials. The particular t of activities that appears to best hieve the manager's goals can then be lopted.

Computer program TIMHAB, described in tis guide, analyzes both timber and deer fod production on managed forests, estinates timber data annually, evaluates timbr costs and returns, and estimates deer fods weekly or monthly. Inputs and rsults are in units regularly used by forest ad wildlife managers. Both timber and der food data are estimated by summation o separate analyses for individual stands. B varying silvicultural activities, the effts of modifications can be evaluated in tms of both the timber enterprise and der-carrying capacity.

TIMHAB contains equations and consnts applicable to tree and understory species found in loblolly pine (*Pinus taeda* L.) plantations in east Texas and Louisiana. The program can be modified, however, for use with other tree species or geographic areas.

Information to be supplied by the program user includes the following:

1. Periods of growth of woody and herbaceous vegetation and of availability of acorns and other mast.
2. Rotation length, thinning and prescribed burning instructions, and other management controls.
3. Stumpage prices per 100 cubic feet and per 1,000 board feet.
4. Costs per acre of precommercial thinning, planting, prescribed burning, and administration.
5. Area, site index, site preparation method, years since cutting, years since burning, and working group assignment of each stand.
6. Average diameter (d.b.h.), average height, number of trees per acre, and age of each stand. Separate values are needed for the overstory pines, midstory hardwoods, and understory pines.

TIMHAB uses these data plus equations and constants contained in the program to compute the following:

1. For each week or month of each year, separate estimates of available digestible dry matter, crude protein, phosphorus, and gross energy expressed as deer-days of use per acre and as acres per deer. Estimates are based on accessible, preferred foodstuffs and estimated metabolic needs for growth of an average deer. Each

---

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category of food (grasses, forbs, browse twigs, browse leaves, berries and other soft mast, acorns, and mushrooms) is included in available supply only during the period when the category is eaten by deer. No reductions are made for deer already on the area or for consumption by other species.

2. Volume and value of the timber harvested each year.
3. Total for each year of the fixed costs and the costs of all activities.
4. Volume and value of the timber growing stock at the end of each year.
5. Rate of return from the timber operation on the initial growing stock value.

Returns from hunting leases are not included in the economic analyses. These can be added when more is known about deer population responses to variations in the food supply. Meanwhile, each program user should consider projected deer food changes in terms of their effect on lease income.

EXAMPLE AND AVAILABILITY

Types of information produced by TIMHAB are illustrated by the results of a hypothetical 10-year simulation tabulated in the Appendix. Total output consists of two pages reporting conditions at the beginning of simulation, one page of food potentials for each of the years simulated, and four pages of economic analyses. For brevity, only the first and tenth pages of the 10 annual summaries of deer food potential are shown.

The hypothetical planning unit consists of two working groups, one managed for sawlog production and one for pulpwood. Printed on the two pages headed "Conditions at Start of Simulation" are initial timber volumes and values and a record of the management options for each working group. Among other things, they report for working group 1 a sawlog rotation of 70 years, with each stand prescribed burned every 7 years beginning at stand age 22. For working group 2, the rotation is 30 years, with no intermediate cuts or burns (interval same as rotation). Deer-days of use and acres per deer are reported for 12 time units (i.e., months) each year. In the remaining pages, which report year-end status and deer food, values are for the planning unit, including both working groups.

The hypothetical situation was designed to perform most of the possible computations and is not suggested as a program of management for loblolly pine plantations. Numerous combinations of possible alternatives as well as published recommendations for management (Blair and Enghardt 1976) can be simulated by a user of TIMHAB.

TIMHAB was written in ANS standard FORTRAN IV and has been tested on XEROX 560, CDC 6400, and UNIVAC 1108 computers. Program length, including common blocks, is 23,100 (decimal) words.

A listing of the FORTRAN program or a source deck may be obtained from the Southern Forest Experiment Station, Box 7600 SFA Station, Nacogdoches, Texas 75962. Requests for punched cards should indicate whether a 026 (Hollerith) or a 029 (EBCDIC) character code is desired.

STATUS OF TIMHAB

TIMHAB is designed as an interim tool to be improved periodically as new and better information becomes available. To complete the model and computer program, some preliminary equations and constants are included, and a few options are provided for future use, for which necessary information is now lacking. These items are identified by comment statements in the program.

Simulation of an activity can indicate profitable areas of future studies and encourage reanalysis of existing data to obtain new information. TIMHAB is being described and made available now partly in the hope that it will stimulate and guide such effort. Work is already underway to obtain replacements for some of the preliminary equations and constants. To keep the program up-to-date as new information becomes available, the long job of programming need not be repeated since improvements require only localized changes.

TIMHAB is not yet a completed, operational management tool, and the effect of all the equations acting together will be unknown until the model is validated. Confidence in the results can be no greater than the degree of confidence that can be placed in all equations and constants. Reliability will increase, however, as the weaker equations and constants are replaced with improved versions. In the meantime, differences in the results of two or more runs are best examined in relation to each other, not as absolute numerical changes in timber or deer food production.

Validation of this simulation model in the usual manner is not now possible. Data on understory production of nutrients and on the metabolic needs of deer are scarce and expensive to obtain. Everything available was incorporated in the model described by the program. Data are now being obtained from long-term studies that will permit future tests of nutrient computations and overstory-understory interactions. Comparisons involving the timber equations are discussed elsewhere (Myers 1977).

One limited test of the program indicates that TIMHAB can produce reasonable results. Tree and understory growth, timber cutting, tree planting, and periodic burning on several stands in a deer enclosure were simulated for 12 years. Projected months of maximum and minimum potential carrying capacity, the pattern of seasonal change in capacity, and responses to timber treatments were as expected from studies of the actual system. Computed potential minimum carrying capacity was not materially different from that of similar stands studied elsewhere.

DESCRIPTION OF TIMHAB

Computer program TIMHAB consists of a main program and 19 subroutines that estimate the production of trees and understory vegetation, quantities of timber harvests and thinnings, costs and effects of other silvicultural operations, and carrying-capacity for white-tailed deer. To facilitate future modification and improvement of the program, all equations and constants are contained in five subroutines.

Operations performed by each routine and the sources of equations and constants are described in this section and are identified by comment statements in the program. Subsequent sections of this paper describe the variables of the data deck and the procedures for program modification.

Several terms used in subroutine descriptions are defined below. Their correct usage is essential for proper preparation of a data deck.

1. Planning unit--the entire area simulated by one computer run. It could be as large as 199,980 acres, in the unlikely event that each of the subunits should be of maximum size.
2. Planning subunit--a subdivision of the planning unit. Each must be uniform in stand age and structure, silvicultural treatment, etc., and therefore a subunit corresponds to a timber manager's definitions of a stand. The term subunit is used when reference is made to both the timber stand and the understory. TIMHAB now permits simulation of a planning unit with 200 subunits of up to 9,999.9 acres each. It can be modified to increase the allowable number of subunits.
3. Working group--a series of subunits or stands of the same forest type and managed by the same silvicultural system. Up to four working groups may be defined by the program user. Working group 4 must be reserved for hardwood stands, even though growth and other equations for hardwood stands do not yet appear in TIMHAB.
4. Midstory--hardwood trees and shrubs, growing in pine stands, that are tall enough to have a measurable diameter 4.5 feet above the ground. The term does not include a hardwood understory in a hardwood stand.

Main Program

The main program performs the following operations:

1. Calls 12 subroutines to perform computations and other operations in the proper sequence (fig. 1). Each subunit is processed for each week or month of every year, and results for all subunits are combined for printing.
2. Tests whether each class of food (trees, herbaceous vegetation, shrubs, berries and other soft mast, acorns, and mushrooms) is in its period of growth or dormancy and adjusts quantities for growth or losses.
3. Calls a subroutine to determine if a scheduled thinning, prescribed burning, or regeneration cutting is due. Tree stands may be regenerated by (1) clearcutting and planting, (2) seed-tree method, (3) two-cut shelterwood, or (4) three-cut shelterwood.
4. Increases the (1) age of each stand, (2) number of growing seasons completed, and (3) number of years since cutting and burning, by an increment equal to the simulation time unit (week or month).

Subroutine INIT

INIT is called by the main program to assign an initial value of zero to numerous variables.

Subroutine BASIS

BASIS is called by the main program to read initial values from the data cards described in the next section. The fraction of a year represented by the selected time unit, 1 week or 1 month, is computed.

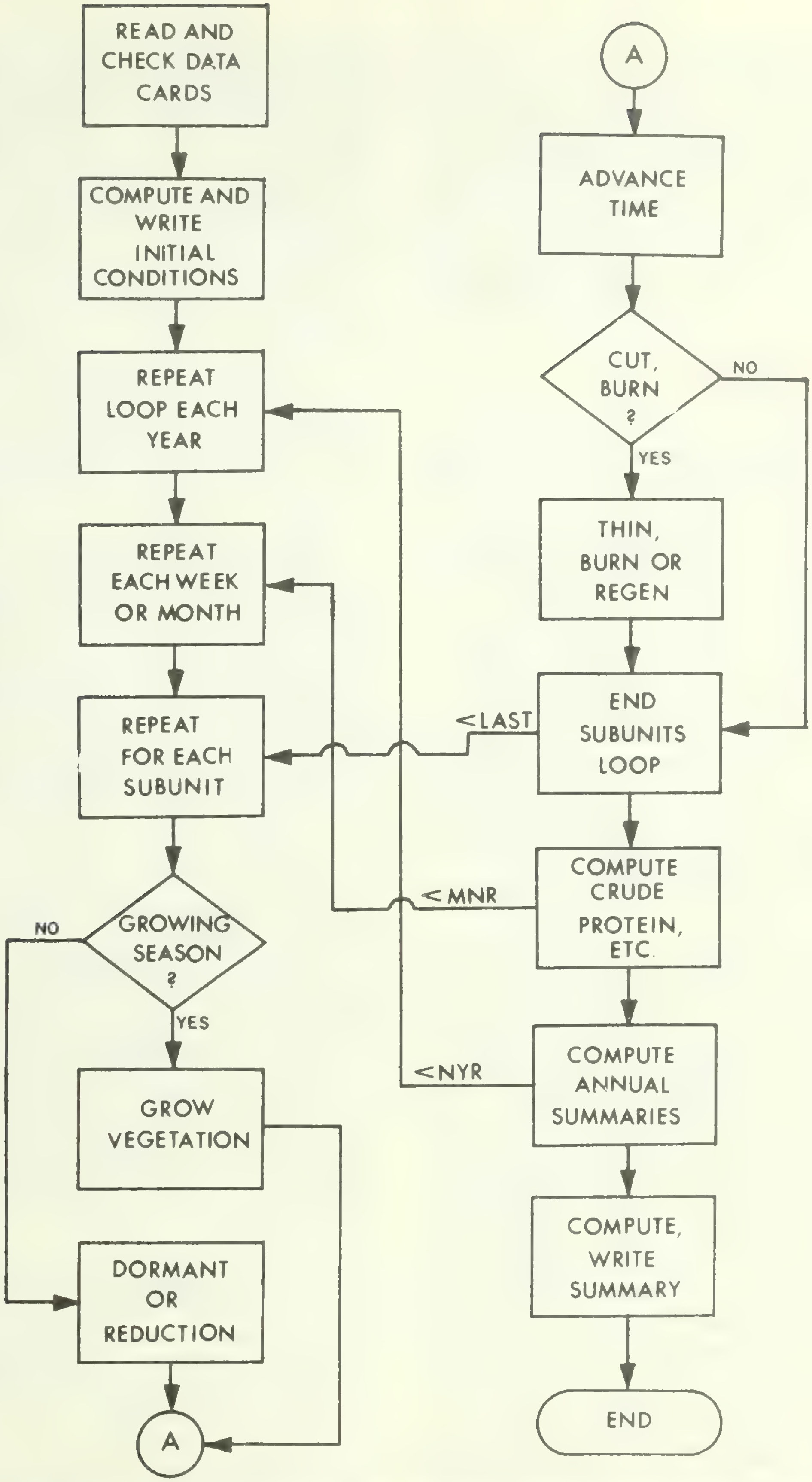
Subroutine ERROR

ERROR is called by the main program to test the values of variables entered by the program user that define (1) growing seasons, (2) number of years to be simulated, (3) number of simulation periods in 1 year, (4) length of cutting cycle, and (5) length of rotation. Any improper value terminates the computer run with an error message. Cycle and rotation lengths are tested only for working group 1, to allow processing of fewer than four working groups.

Subroutine START

START is called by the main program to compute initial conditions on the planning unit on January 1 of the first year of simulation and to determine several constants needed in subsequent computations. The following values are determined:

1. Proportions of annual production of browse, herbage, and soft mast produced during each period of the growing season.
2. Number of weeks or months in the non-growing season, separately for browse, herbage, and soft mast, from information on data card type 3.
3. Initial growing stock volumes in board and cubic feet and their value. Cubic volumes do not include volumes of sawlogs or of trees in stands younger than a minimum age specified by the program user.
4. Decimal parts of a year to be added to stand ages read from the data cards. This modification distributes dates of simulated thinnings and regeneration cuttings throughout the year. Amounts added to each age are computed with a simple congruential pseudorandom number generator in START.
5. Theoretical initial number of pine trees per acre. The equation for mortality in unthinned stands uses initial density as an independent variable. For plantations already established when simulation begins, initial density is computed from a restatement of this equation. Plantations created during the simulation period will each contain the number of trees specified by the program user.
6. Ovendry weights of accessible and preferred grasses, forbs, soft mast, browse leaves, and browse twigs present when simulation begins on January 1 of the first year. An initial amount is computed separately for each planning subunit, on the basis of records of prior cutting and prescribed burning from data cards read by subroutine BASIS. Weights of acorns and mushrooms are not computed by START but by ETEX.



gure 1.—*Sequence of operations in program TIMHAB. Test for growing season is made for each food source every time that step in the sequence is reached.*

Subroutine BEGIN

BEGIN is called by the main program to write two pages describing conditions at the start of the simulation period (Appendix). These are the first two pages written during the simulation run; they report (1) initial volume and value of the growing stock, (2) controls on management for each working group, (3) unit costs and prices, and (4) the season of use by deer of each of seven classes of food.

Subroutine UNDR

UNDR is called by the main program and by subroutine START to select two subroutines that compute the increases or decreases of understory vegetation, fruits, or acorns. Selection is based on a locality code on a data card for each subunit. In its present form, TIMHAB contains two subroutines applying to understories and deer foods in loblolly pine plantations in east Texas and Louisiana (locality code 1). Subroutine ETXBEG computes amounts of each type of forage present at the start of simulation. Subroutine ETEX computes subsequent changes in forage amounts. Comparable routines applicable to other localities can be added as equations and constants become available.

Subroutine TREE

Subroutine TREE is called by the main program and subroutines THNTR, START, REMOV, or REGEN whenever volume, growth, or mortality of tree stands is computed. Purpose of TREE is similar to that of UNDR, described above. The present version of TIMHAB contains two subroutines that apply to loblolly pine plantations in east Texas and Louisiana. Subroutine LOBPL contains equations for loblolly pine and is called when species code 1 appears on the appropriate data card. Subroutine HRDWD, called by species code 2, contains equations and constants for hardwoods growing in loblolly pine plantations.

Subroutine CHEK

CHEK is called by the main program each week or month of the simulation period. Current stand age of each subunit, plus the random amount computed in START, is compared with scheduled times of prescribed burning, thinning, and regeneration cutting to see if one of these operations is to be performed. Prescribed burning costs are added to total expenditures for the year in CHEK. One of the cutting subroutines (THNTR, REGEN, REMOV) is called by CHEK whenever a thinning or regeneration cutting is to be executed.

Thinnings will be made as frequently as specified by the program user, and options include not thinning during the rotation. Basal areas to be reserved after initial and subsequent thinnings are determined by the user.

Four regeneration methods may be specified: (1) clearcutting and planting, (2) seed-tree method, (3) two-cut shelterwood, and (4) three-cut shelterwood. More than one method may be used on a planning unit by assigning stands to be regenerated by the same method to the same working group. Three working groups may be designated for pine stands. Working group 4 must be reserved for hardwood stands.

Subroutine FOOD

For each week or month of every year, FOOD is called by the main program to compute potential deer-days of use available from each subunit. Potentials are based on the yield of preferred foods and on the following estimated daily nutritional requirements (ovendry basis) for growth of a 100-pound white-tailed deer: (1) 1.8 pounds of digestible dry matter, (2) 6,300 Kcals of gross energy, (3) 0.016 pound of phosphorus, and (4) 0.54 pound of crude protein (French and others 1955, Magruder and others 1957, Dietz 1971, Verme and Ullrey 1972).

The present version of TIMHAB uses only the estimated daily requirements listed above. Subroutine FOOD can be expanded readily to use values that reflect seasonal changes in requirements, as the information becomes available.

The first operation performed by FOOD is to define the period of use of each class of food (Short 1971, Harlow and Hooper

72). Deer food of any class present ring its season of non-use is excluded om carrying-capacity calculations.

Subsequent operations are performed parately for each subunit to account for e effect of recent cutting or prescribed rning. Calculations are made for available digestible dry matter, crude protein, osphorus, and gross energy. The operans, of which the first seven are repeated r each subunit, are as follows:

1. Reduction of available food in the interior of large openings to account for non-use by deer, if this option is specified by the user.
2. Reduction of preferred browse leaves by 50 percent so the photosynthetic surface needed to keep the shrubs healthy will not be included in forage available for deer.
3. Computation of the nutrients and energy contributed by acorns, if present (Prosser and Brown 1966, Short 1971, Short 1975).
4. Computation of the nutrients and energy contributed by mushrooms and soft mast. Separate factors from a pending publication by Blair and others[1] are used for each of the four seasons of the year.
5. Computation of the nutrients and energy contributed by accessible preferred herbage and browse. Separate factors are used each season for forbs, grasses and grass-likes, browse leaves, and browse twigs (Short and others 1975, Blair and others[1]).
6. Computation of changes in the nutrient and energy content of herbaceous vegetation seasonally in the first 2 years after a burn (Halls and others 1952).
7. Adjustment, by season, in the nutrient and energy content of browse during the first and second years after a prescribed burn (Lay 1957).
8. Computation of the deer days of use per acre potentially available on the planning unit for the time period being simulated.

Nutrient and energy factors referred to above are also used in computing the contributions of forage in a clearcut. Separate factors for clearcuts can be added to the program, when available, if future research indicates this is necessary. Appropriate transfers of control to incorporate separate factors for clearcuts, if needed, are provided and identified by comment statements.

Subroutine SUMRY1

SUMRY1 is called by the main program at the end of each year simulated. It performs the following operations for each subunit of the planning unit:

1. Computes the volume and value of the timber growing stock at the end of the year. Sawlog volume of each subunit is added to board-foot total if it equals or exceeds minimum commercial board-foot limits. Non-sawlog parts of each stand are included in cubic volumes. Sawlog volumes below the specified minimum are assigned to cubic volume if both minimum cubic-foot limits and minimum age for inclusion in growing stock have been reached.
2. Computes the current value of any commercial cuts made during the year. The sum of these values less costs is the net income for the year; net income plus value of growing stock is reported as net worth.
3. Increases unit costs and prices by percentages specified by the program user. At the user's option, the 10 cost and price values may be held constant.
4. Computes acres required per deer for each of four measures of nutrients, based on values from subroutine FOOD. Values for the planning unit are compiled by week or month for each year.
5. Prints, for each week or month, available deer-days of use per acre and acres required per deer to supply needed quantities of digestible dry matter, crude protein, phosphorus, and gross energy. A separate page (two, if time period is 1 week) is

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[1] ir, R. M., H. L. Short, and E. A. Epps, Jr. Seasonal nutrient il and digestibility of forage from a young pine plantation M uscript in preparation

printed each year of the simulation period.

Subroutine SUMRY2

SUMRY2 is called by the main program after all years of the period are simulated. It computes values needed, in addition to initial growing stock value, to determine the internal rate of return from the timber operation. These values are (1) summations of the volumes cut annually and of their values, (2) a table of compound interest discount factors for rates from 1.0 to 15.5 percent for each year simulated, (3) discounted values of annual costs and returns and of the final value of the timber growing stock, and (4) present worth of net earnings (including increases in growing stock) of the timber operation at each discount rate from 1.0 to 15.5 percent.

As mentioned in the introduction, income from the sale of hunting privileges is not now included in this summary analysis.

Subroutine FINAL

FINAL is the last subroutine called by the main program. It writes four pages summarizing timber operations during the simulation period. The first page (numbered 11 in the Appendix) presents the cubic- and board-foot volumes and values of pines and hardwoods harvested each year. The second page records the volume and value of the pine and hardwood growing stock at the end of each year simulated. The third page shows operating cost, gross and net income, value of growing stock, and net worth for each year of the period. The last page of the simulation record shows the present values at each discount rate of the items computed in subroutine SUMRY2. The entries in the column headed "net present worth" are the discounted values of all periodic net income, including net increases in growing stock but excluding the value of the original growing stock. These values are used to determine the rate earned on the growing stock investment during the simulation period.

Subroutine THNTR

THNTR is called by subroutine CHEK to simulate thinnings to standards prescribed by the program user. This simulation requires performance of the following operations, each of which involves a call to TREE:

1. Computation of volumes before and after thinning and of the volume removed.
2. Reduction of the number of trees per acre as a result of thinning and corresponding changes in other stand variables.
3. Addition of volumes removed to cubic- or board-foot totals. Cuts are treated as harvests of board feet plus additional cubic volume if board-foot volume equals or exceeds minimum commercial limits per acre. Harvested volumes are added to cubic-foot totals if they cannot be classed as commercial sawlog cuts and if commercial standards for cubic volumes are reached.
4. Addition of returns from commercial thinnings to total income for the year. Cost of a noncommercial thinning is added to total expenses for the year. Administrative and other costs per 100 cubic feet or per 1,000 board feet are added to annual expenses.
5. Removal of midstory hardwoods during the thinning of pine stands, unless hardwoods are to be left uncut.

Subroutine REGEN

REGEN is called by subroutine CHEK to simulate clearcutting and planting and the final cuts of the shelterwood or seed-tree methods. The following operations are performed:

1. Computes volume removed and its value. Volumes are assigned to board or cubic feet as in subroutine THNTR. Stumpage income and sale costs are added to annual totals of income and costs.
2. Simulates clearcutting and planting. Average d.b.h. and other variables describing the rotation-age stand and the understory are reduced to zero. The stand is assigned a new number of trees per acre equal to the planting density selected by the program

user. Stand age is set to a negative value sufficient to insure a minimum of 9 months' delay between cutting and replanting for control of pales weevil (Hylobius pales Herbst.). Cost of planting is assigned to the year of cutting or to the following year, depending on when the delay period ends. Number of years since burning is set to zero if site preparation includes burning. Hardwoods may be reserved if desired.

3. Simulates final cuts of the seed-tree or shelterwood methods. Values of understory variables are assigned to equivalent overstory variables, and the understory variables are given values of zero.

Subroutine REMOV

REMOV is called by subroutine CHEK to simulate removal (partial) cuts of the seed-tree and shelterwood methods. It computes commercial board- and cubic-foot volumes removed, costs, and returns as does subroutine THNTR. Average d.b.h. and other variables describing the residual seed trees or shelterwood are computed as for intermediate thinnings. Subroutine TREE is called to initiate these computations.

A new seedling stand is established after each removal cut. Average age of the reproduction depends on the number of removal cuts made and on the length of the interval between them. Number of pine seedlings established per acre is specified by the program user. The number should be based on local experience with the regeneration method being simulated.

Subroutine ETEX

ETEX contains species-specific equations nd constants used to compute seasonal ncreases and decreases of understory vegtation and the production of acorns and ther fruits. It is applicable to species and onditions in the loblolly pine plantations f east Texas and Louisiana. ETEX conists of 12 parts, called individually by the ain program except as noted below. Purose and content of each of the 12 parts re as follows:

Part 1—to compute the ovendry weights f grasses and forbs produced on a subunit. Production in plantations aged 7 years or more is computed from total basal area of the overstory and midstory (Halls and Schuster 1965). Weights of grasses and forbs produced after clearcutting and site preparation but before planting are determined in Part 11.

Production in a plantation less than 7 years old is computed from plantation age. Data used to obtain the equations came from Stand 6, Stephen F. Austin Experimental Forest, Texas. The equation for forbs is

$$\text{Log}_e Y = 7.51238 - 0.54305A \qquad R = 0.969$$

where Y = pounds of ovendry forbs per acre
A = plantation age.

The equation for grasses is

$$\text{Log}_e Y = 7.68388 - 0.34197A \qquad R = 0.986$$

where: Y = pounds of ovendry grass per acre
A = plantation age.

Weight of herbage on each subunit is increased an appropriate amount if the area was prescribed burned within the previous 3 years (Lay 1956). Part 12 of ETEX is called to reduce the amount of herbage to zero if burning takes place during the current week or month.

Part 2--to reduce the grasses and forbs on each subunit during the winter months. In the absence of research data, a percentage of the amount present at the end of the previous week or month is subtracted from every subunit total during each period of the non-growing season.

Part 3--to compute the ovendry weight of berries and other soft mast produced on a subunit. Production on a subunit not recently prescribed burned is computed from total overstory and midstory basal area with an equation by Hastings (1966). Production is set to zero during the first year after a prescribed burn. It is reduced below the amount given by Hastings' equation during the following 2 years (Lay

1956). No reduction is made soon after partial cutting because necessary information is lacking. Statements have been provided in ETEX to permit inclusion of the effects of partial cutting when research results become available.

Part 4--to compute the reduction of soft mast due to decay, as described for grasses and forbs in Part 2.

Part 5—to compute the ovendry weights of browse leaves and twigs produced on a subunit. In plantations aged 7 years or more, production is computed from two variables—overstory and midstory basal areas (Blair 1967). In plantations less than 7 years old, production (high- and medium-preference species only) is calculated from the following equations based on data from the Stephen F. Austin Experimental Forest, Texas:

$$Y = 353.3714 + 50.8061A^2 \qquad R = 0.988$$
$$\text{Log}_e Y = 7.77840 - 0.36945AG \qquad R=0.989$$

where:

Y = pounds of ovendry browse per acre.
A = plantation age if less than 3 years.
AG = plantation age from 3 to 7 years.

Browse production is reduced to zero in the first week or month after prescribed burning. It increases from 44 to 94 percent of the amount in unburned stands over the following 3 years (Lay 1956).

Available information is inadequate to estimate browse losses due to partial cutting of the overstory. Provision has been made in ETEX for future inclusion of the appropriate statements. Production after clearcutting and site preparation but before plantation establishment is computed in Part 11.

Unpublished constants obtained by R. M. Blair, Southern Forest Experiment Station, are used to reduce total weight of browse to that of high- and medium-preference species only. Other constants from Blair subdivide total preferred browse into the weights of leaves and twigs. Separate constants are available for subunits with and without a midstory.

Part 6—to reduce the browse leaves on each subunit during the winter months. Computations parallel those described for Part 2. After autumn leaf abscission, leaf weight drops sharply until it approximates the average amount of nonconifer, evergreen browse leaves present.

Part 7—to compute the ovendry weight of acorns available on a subunit if oaks of acorn-bearing size are present. The equations in ETEX are mathematical expressions of production per square foot of basal area, by diameter classes for selected species, from a table published by Goodrum and others (1971). Amounts computed exclude quantities eaten by arboral feeders and allow 21 percent for losses to weevils.

The percentage of the acorn crop available to deer during any week or month of the autumn and winter is based on 8 years' record of catch in seed traps on the Stephen F. Austin Experimental Forest, Texas.

Part 8--to set the amount of acorns present to zero during the period of nonavailability.

Part 9--to compute the ovendry weight of mushrooms produced on each subunit. Preliminary seasonal yields obtained by R. M. Blair are included in ETEX. Work is underway to obtain more detailed information.

Part 10--to compute rates of change used in other parts of ETEX. Each rate is the dx/dt used in the Euler solution of the production equations. This part is called once by subroutine START at the beginning of simulation.

Part 11--to compute the ovendry weight of forbs, grasses, and browse on clearcuts not yet replanted to trees. Production per acre is estimated for five means of site preparation : (1) none, (2) burning and discing, (3) KG blade, (4) chopping, and (5) burning (Stransky 1976). Constants provided by R. M. Blair divide total browse into weights of leaves and of twigs.

Part 12—to reduce the weight of herbage and browse on a subunit to zero immediately after a burn, as called for by other parts of ETEX.

Subroutine ETXBEG

ETXBEG is called by subroutine START as part of the determination of initial conditions on the planning unit. It contains most of the equations and constants found in subroutine ETEX and provides the same alternative computations for prescribed burning and clearcutting. The two subroutines differ in that the computations in ETXBEG estimate the forage present on January 1 of the first year of the simulation period. Separate computations are made for the forbs, grasses, soft mast, and browse on each subunit. Mushrooms and acorns are not computed in ETXBEG but are computed in ETEX as the simulation period begins.

Subroutine LOBPL

Subroutine LOBPL is called by subroutine TREE whenever an equation applicable to the overstory of loblolly pine plantations is needed. Like ETEX, subroutine LOBPL consists of several parts, each of which may be called independently. The equations and constants in the 10 parts of LOBPL are described elsewhere (Myers 1977). Briefly, they consist of the following:

1. An equation for basal area growth as a function of current basal area, stand age, and site index (Clutter 1963).
2. Equations for estimating average dominant and codominat height from stand age and site index (Lenhart 1972, Farrar 1973).
3. Initial average d.b.h. of young stands as a function of initial density, age, and site index.
4. Merchantable cubic-foot volumes inside bark per acre in trees 5 inches in d.b.h. and larger to a 4-inch top. Volumes are computed from average d.b.h., height, and basal area.
5. Board-foot volumes per acre in trees 9 inches in d.b.h. and larger to a 7-inch top. Volumes are based on the Scribner Rule and are obtained from cubic-volumes and ratios of board feet per cubic foot.

6-8. Changes in average stand d.b.h., average dominant and codominant height, and number of trees per acre resulting immediately from partial cuttings.

9. Noncatastrophic mortality in unthinned stands as a function of stand age, initial density, and height (Smalley and Bailey 1974).
10. Noncatastrophic mortality in previously-thinned stands from average stand d.b.h.

Subroutine HRDWD

HRDWD is called by TREE whenever growth or mortality of the hardwood midstory is calculated. It has 10 independent parts arranged in the same sequence as LOBPL. Several of the parts, however, are not required for proper execution of program TIMHAB. This structure of subroutine HRDWD is used to permit computation of overstory and midstory values in the same loops. The parts of HRDWD essential for midstory computations are as follows:

Part 1—to compute the increase in average d.b.h. of the midstory. Annual increases in d.b.h. of 0.12 to 0.20 inch reflect both growth in d.b.h. and increase in the number of stems more than 4.5 feet tall.

Part 3—to determine the initial average d.b.h. of young midstories when they reach an average height of 4.5 feet.

Parts 5, 6, 7—to assign age and other stand values to the future midstory after removal of the previous midstory during thinning or regeneration of pine stands. The three parts contain the same FORTRAN statements. Most variables describing the midstory are assigned values of zero. Age is set at -2.0 years and density at 80.0 stems per acre, thus estimating 80 stems taller than 4.5 feet 2 years after cutting.

Part 10—to change the number of midstory stems per acre. The equation, based on the data used for Part 1, reflects the combined effect of noncatastrophic mortality and any increase in the number of stems more than 4.5 feet tall. Numbers increase for a number of years and then decline. Rate of change and the stand age at time of first decline vary with total overstory and midstory basal area.

Constants and equations describing midstory changes are based on limited data from one locality (Alexander State Forest, Louisiana) that were obtained by R. M. Blair for another purpose. Research on the development of hardwood midstories should be a high priority item for those interested in multiple use of Southern forests.

USER-SUPPLIED INFORMATION

Persons using program TIMHAB must supply values of 124 variables on data cards (table 1). Ninety-six of the variables describe management decisions and control program execution. One set of the other 28 variables is needed for each planning subunit to be simulated.

Data cards are identified in table 1 by type numbers that, except for subunit information, show their sequence in the data deck. A data deck will consist of (1) one card each of types 1 to 3; (2) four cards of type 4 in the sequence 1, 2, 3, 4 for working groups 1, 2, 3, and 4; (3) one card each of card types 5 and 6; (4) one card each of types 7 and 8 for each subunit, and (5) one card of type 9.

Card types 7 and 8 are read for one subunit before reading begins for the next subunit. Sequence of these cards is therefore 7, 8, 7, 8, etc., until the required number has been read.

Timber Operations

Data card type 4 has values that control intermediate and regeneration cuts, summations of commercial volumes, planting, and prescribed burning.

Five variables, columns 17 through 36, control execution of regeneration cuts and determine the regeneration method to be simulated. For clearcutting, age at first regeneration cut is entered on card 4, and the other regeneration variables are left blank or given values of zero. Seed-tree cutting and two-cut shelterwood require nonzero values for the first three regeneration variables: REGN(L, 1)--stand age at first cutting; REGN(L, 2)—age at seed-tree or shelterwood removal; and VLLV(L, 1)—basal area to be left as a seed source at age REGN(L, 1). Three-cut shelterwood requires that all five regeneration variables be assigned values larger than zero.

Regardless of regeneration method, the age of first regeneration cut, columns 17 to 20, must never be assigned a value of zero if any subunits are assigned to that working group.

Thinnings and prescribed burnings are scheduled by variables in columns 1 through 16 and 49 through 56 on card type 4. The first treatment will occur or is assumed to have occurred at a stand age of THN1(L) or BURN(L). Subsequent thinnings and burnings will be simulated at intervals of CYCL(L) or BRNCY(L) years.

Midstory Retention

The hardwood midstory may be either removed or retained when pine stands are thinned or regenerated. Midstories of a working group are retained if DECID(L) is assigned a nonzero value on card type 4. Otherwise, they will be removed. Variable HDAGE(L) is used to indicate the age at which reserved midstory trees will be removed some time in the future. This option is provided to show how wood production and deer food supply are affected by retaining hardwoods during the thinning of a pine overstory.

Working Group Assignments

Four cards of data card type 4 are needed in the data deck, one for each of the four possible working groups to which stands of the planning unit can be assigned. A working group consists of all stands for which rotation length and other variables on card type 4 are equal. Cards of type 4 are arranged in the order working group 1, 2, 3, and 4 in the data deck.

Working group 1 must be one of the working groups established for the planning

Table 1.—*Order and contents of the data deck.*

Card type	Variable name	Punch card columns	Format	Description of variable
1	FORET(N)	1-24	6A4	Name of forest, block, or tract in which planning unit is located.
2	NYR	1-2	I2	Number of years to be simulated.
	INVL	3-7	A5	Time period for which each computation of change is made. Enter "WEEK" or "MONTH," left justified. Will be read as A4 format.
	DESCR(N)	8-79	18A4	Name, location, or other description of the planning unit simulated.
3	ITR1	1-3	I3	Week or month when tree growth starts. Enter number from 1-12 if INVL is "MONTH" and from 1-52 if INVL is "WEEK."
	ITR2	4-6	I3	Week or month when tree growth ends. Same code as for ITR1.
	IHB1	7-9	I3	Week or month when herbaceous growth starts. Same code as for ITR1.
	IHB2	10-12	I3	Week or month when herbaceous growth ends. Same code as for ITR1.
	ISH1	13-15	I3	Week or month when growth of shrubs and small understory hardwoods starts. Same code as for ITR1.
	ISH2	16-18	I3	Week or month when growth of shrubs and small understory hardwoods ends. Same code as for ITR1.
	IAC1	19-21	I3	Week or month when acorns first become available to deer. Same code as for ITR1.
	IAC2	22-24	I3	Last week or month when acorns are available to deer. Same code as for ITR1.
	MST1	25-27	I3	Week or month when berries and other fruits become available to deer. Same code as for ITR1.
	MST2	28-30	I3	Last week or month when berries and other fruits are available to deer. Same code as for ITR1.
4	THN1(L)	1-4	F4.0	Stand age when first thinning, if any, is made. Set equal to rotation length if no thinnings will be made.
(need	THIN(L)	5-8	F4.0	Basal area in square feet to be left after initial thinning.
four	DLEV(L)	9-12	F4.0	Basal area to be left in partial cuts after the first.
cards)	CYCL(L)	13-16	F4.0	Number of years between scheduled thinnings. Set equal to rotation length if no thinnings will be made.
	REGN(L,1)	17-20	F4.0	Stand age when first regeneration cut is made. Must never equal zero. This is the age for clearcutting if following regeneration variables have values of zero.
	VLLV(L,1)	21-24	F4.0	Basal area to be left at age REGN(1). Will be zero for clearcutting.

Table 1.—*continued*

Card type	Variable name	Punch card columns	Format	Description of variable
	REGN(L,2)	25-28	F4.0	Stand age at which second regeneration cut, if any, will occur. Age for removal of seed trees or second cut of shelterwood.
4	VLLV(L,2)	29-32	F4.0	Basal area to be left at age REGN(2). Will be zero except for three-cut shelterwood.
	REGN(L,3)	33-36	F4.0	Stand age at which third regeneration cut, if any, will occur. Final cut of three-cut shelterwood.
	COMBF(L)	37-40	F4.1	Minimum commercial cut in thousands of board feet per acre.
	COMCU(L)	41-44	F4.1	Minimum commercial cut in hundreds of cubic feet per acre.
	PLNT(L)	45-48	F4.0	Number of trees to be planted per acre. Also number of established seedlings expected from seed trees or shelterwood.
	BURN(L)	49-52	F4.0	Stand age at time of initial prescribed burning.
	BRNCY(L)	53-56	F4.0	Number of years between prescribed burnings.
	SDAGE(L)	57-60	F4.0	Age of planting stock at time of transplanting to the planning unit.
	DECID(L)	61-64	F4.0	Instructions to save (DECID=1) or cut (DECID=0) midstory hardwoods when overstory pine is thinned or regenerated.
	HDAGE(L)	65-68	F4.0	Age at which midstory hardwoods will be cut. Needed only if DECID(L) has a nonzero value.
5	AGMRCH	1-5	F5.0	Minimum stand age for volume to be included in summations of growing stock.
	BFPIN	6-10	F5.2	Stumpage value of 1,000 board feet of pine.
	CUPIN	11-15	F5.2	Stumpage value of 100 cubic feet of pine.
	BFHWD	16-20	F5.2	Average stumpage value of 1,000 board feet of hardwoods.
	CUHWD	21-25	F5.2	Average stumpage value of 100 cubic feet of hardwoods.
	CHGPR	26-30	F5.2	Percentage increase in stumpage prices annually. Enter zero for constant prices.
	CPLT	31-35	F5.2	Planting cost per acre, including site preparation.
	CTHN	36-40	F5.2	Cost per acre of a precommercial thinning.
	CBRN	41-45	F5.2	Cost per acre of periodic prescribed burning, not including burning for site preparation.
	ACCST	46-50	F5.2	Annual costs per acre for taxes, protection, supervision, etc.
	CUCST	51-55	F5.2	Cost of marking, supervision, etc. for each 100 cubic feet harvested.
	BFCST	56-60	F5.2	Cost of marking, supervision, etc. for each 1,000 board feet harvested.
	CHGCS	61-65	F5.2	Percentage increase in costs annually. Enter zero for constant costs.

Table 1.—*continued*

Card type	Variable name	Punch card columns	Format	Description of variable
6	ENTRY	1-4	F4.0	Distance (in feet) from uncut edge that a white-tailed deer will enter a clearcut or a plantation less than 3 years old. Enter zero if area option is not wanted.
7	IPS(J)	1-3	I3	Identification number of the stand or planning subunit.
(one per sub-	ACRE(J)	4-8	F5.1	Area in acres of the subunit described on the card.
unit)	SITE(J)	9-12	F4.0	Site index of the subunit. Base age must be 50 years to match that used in the growth equations.
	MAC(J)	13-15	I3	Locality code number used to select the subroutine that contains constants and equations applicable to understories in the locality of the subunit. Only code 1, east Texas-Louisiana, is now available.
	STPRP(J)	16-18	F3.0	Site preparation treatment during regeneration. Code as 1 = do nothing, 2 = burning, 3 = chopping, 4 = KG blade, 5 = discing.
	IWGP(J)	19-21	I3	Working group assignment of the subunit. Working group 4 is reserved for hardwood stands.
	NABR1(J)	22-24	I3	Identification number of the subunit north of the subunit described. Enter zero if on north boundary or if area option not wanted.
	NABR2(J)	25-27	I3	Identification number of the subunit east of the subunit described. Enter zero if on east boundary or if area option not wanted.
	NABR3(J)	28-30	I3	Identification number of the subunit south of the subunit described. Enter zero if on south boundary or if area option not wanted.
	NABR4(J)	31-33	I3	Identification number of the subunit west of the subunit described. Enter zero if on west boundary or if area option not wanted.
	YRCUT(J)	34-37	F4.2	Number of years since a partial or regeneration cut was made on the subunit.
	YRBRN(J)	38-41	F4.2	Number of years since a prescribed burn was made on the subunit.
8	IPS(J)	1-3	I3	Identification number of the stand or planning subunit.
(one per sub-unit)	KAK(1,J)	4-6	I3	Identification number of the species composing the overstory. Limited at present to code 1, loblolly pine.
	DBH(1,J)	7-9	F3.1	Average d.b.h. (inches) of all live trees in the overstory stand.
	HT(1,J)	10-12	F3.0	Average height (feet) of dominant and codominant trees of the overstory.
	DEN(1,J)	13-17	F5.0	Number of live trees in the overstory. Enter value of PLNT if there are no trees present

Table 1.—*continued*

Card type	Variable name	Punch card columns	Format	Description of variable
				but area will be planted some time in the future.
	AGE(1,J)	18-20	F3.0	Age of the overstory. Include seedling age if the subunit is a plantation. For future planting of a treeless subunit, enter a negative value equal to the number of years' delay.
8	KAK(2,J)	21-23	I3	Identification number of the species composing the regeneration under seed trees or a shelterwood. Limited at present to code 1, loblolly pine.
	DBH(2,J)	24-26	F3.1	Average d.b.h. of the regeneration under seed trees or shelterwood, if any.
	HT(2,J)	27-29	F3.0	Average height of potential dominants and codominants of the regeneration.
	DEN(2,J)	30-34	F5.0	Number of live trees in the regeneration under seed trees or a shelterwood.
	AGE(2,J)	35-37	F3.0	Age of the regeneration under seed trees or a shelterwood.
	KAK(3,J)	38-40	I3	Identification number used to select the subroutine containing equations and constants for a hardwood midstory in pine stands. Must be entered even though no hardwoods now present. Limited at present to code 2.
	DBH(3,J)	41-43	F3.1	Average d.b.h. of the hardwood midstory if subunit is a pine stand.
	HT(3,J)	44-46	F3.0	Average height of midstory hardwoods if subunit is a pine stand.
	DEN(3,J)	47-51	F5.0	Average number of midstory hardwoods per acre if subunit is a pine stand.
	AGE(3,J)	52-54	F3.0	Average age of midstory hardwoods if subunit is a pine stand.
	PCTOAK(J)	55-57	F3.0	Percentage of hardwood basal area that is oak. Enter actual percentage or average percentage for the locality even if hardwoods not now present. Base percentage on hardwood overstory if IWGP equals 4.
9	(Punch zero in column 3)			

unit to prevent termination of execution by subroutine ERROR. Working group 4 is reserved for hardwood (not midstory) stands. No assignments may be made to that working group until a subroutine for hardwood stands equivalent to LOBPL has been added to the program.

Each subunit or stand is assigned to a working group by variable IWGP(J) on data card type 7.

Stand Variables

Stand descriptions on data card type 8 apply to conditions just before the simulation period starts on January 1 of simulation year one. Variables in columns 4 through 20 report conditions in the overstory, which at present must be loblolly pine, species 1. Subroutines for other pines may be added when developed. The values punched in columns 21 to 37 describe seedlings under seed trees or a shelterwood. Values are not assigned to this set of variables if seedlings are not present. Variables in columns 38 through 54 apply to the hardwood midstory, if any, in pine stands. Species identification number 2 (to call subroutine HRDWD) must be punched even if the subunit was just burned or prepared for planting. The number will be used in computations of future growth after resprouting.

Subunit Size

Reductions in food availability due to large regeneration areas may be simulated by assigning an appropriate value to ENTRY on data card type 6. ENTRY is the distance (in feet) from a timber edge that a white-tailed deer will enter a clearcut or a plantation less than 3 years old to utilize food there. A checkerboard arrangement of subunits is assumed, although uniformity of subunit size may be ignored if adjacent subunits will bear trees more than 3 years old throughout the simulation period. This option is selected by assigning a nonzero value to ENTRY and entering the identification numbers of adjacent subunits on data card type 7. Punch a zero for ENTRY on card type 6 if the option is not wanted.

Time Intervals

Unit time interval for the simulation may be either 1 week or 1 month. The choice is made on data card type 2. Deer-days of use and acres per deer will be computed for either interval. Simulation intervals of 1 month are appropriate for most computer runs and for the level of precision of the equations and constants currently in TIMHAB.

MODIFICATION OF TIMHAB

TIMHAB can be readily modified to meet the needs of a variety of users. Several possible changes are described below.

Equations and constants now in the program should be replaced by improved versions whenever they become available. All candidates for replacement are in subroutines FOOD, ETEX, ETXBEG, LOBPL, and HRDWD. FOOD contains the four daily nutrition requirements used in TIMHAB and defines the period of use of each food class. It also has the constants that convert ovendry weights of the various food classes to digestible dry matter, crude protein, phosphorus, and gross energy. ETEX and ETXBEG contain constants and equations for acorns and understories. LOBPL performs all computations for pine overstories; HRDWD has the items needed for hardwood midstories.

A change in subroutine FOOD that redefines the period of use of any food requires a corresponding change at the end of subroutine BEGIN. This change is needed to correct the record on the second of the two pages printed by BEGIN that report conditions before simulation starts (Appendix).

Additional subroutines can be included in TIMHAB to provide equations for other species or conditions. New subroutines for understories must follow the sequence used in ETEX and ETXBEG. CONTINUE statements in subroutine UNDR are replaced by CALL statements for the new routines. New subroutines for trees must follow the order of computations in LOBPL or HRDWD. Statements calling them are placed in subroutine TREE. In both UNDR and TREE, order of the call statement labels in each "GO TO" determine the identification number of the locality or species added.

Simulation periods of more than 50 years require changes in (1) dimensions in the common blocks and a DIMENSION statement in SUMRY2 and (2) one DO statement each in INIT and SUMRY2.

Simulation of conditions on more than 200 subunits requires changes in (1) dimensions in the common blocks, (2) two DO statements in subroutine INIT, and (3) one DO statement each in BASIS and START.

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APPENDIX

SAMPLE OUTPUT

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                                             CONDITIONS AT START OF SIMULATION

      UNIT= BOWIE TRACT.                                                                      TOTAL AREA OF UNIT=  6819.0

      SIMULATION SITUATION= TIMBER=DEER RELATIONS ON TRAVIS PLANNING UNIT.

      NUMBER OF INVENTORY RECORDS READ=   60                                   NUMBER OF INVENTORY RECORDS PROCESSED=   60

      TIME UNITS PER YEAR= 12

                                  - - - - - - - - TIMBER VOLUMES AND VALUE, TOTALS FOR PLANNING UNIT - - - - - - - -

STUMPAGE VALUES=           *                                             PINE            HARDWOODS            TOTALS
  PINE                     *
    CUBIC FEET     7.85    *   HUNDREDS OF CUBIL FEET                60396.13               .00            60396.13
    BOARD FEET   109.00    *
  HARDWOODS                *   THOUSANDS OF BOARD FEET               35095.43               .00            35095.43
    CUBIC FEET     3.15    *
    BOARD FEET    24.40    *   VALUE OF CU. FT., DOLLARS               474109.               0.               474109.

                               VALUE OF BD. FT., DOLLARS              3825396.               0.              3825396.

                               TOTAL VALUE, DOLLARS                   4299505.               0.              4299505.

    MINIMUM AGE FOR INCLUSION OF VOLUME IN GROWING STOCK=  10. YEARS.

    MINIMUM VOLUME INCLUDED EQUALS MINIMUM COMMERCIAL LIMITS.

                                        - - - MANAGEMENT SITUATION BY WORKING GROUP - - -

                                                          WG1          WG2          WG3          WG4

                 AGE AT FIRST THINNING, YEARS             21.0         30.0           .0           .0

                 INITIAL THINNING LEVEL, SQ. FT.          80.0         80.0           .0           .0

                 SUBSEQUENT THINNING LEVEL, SQ. FT.       90.0         90.0           .0           .0

                 MINIMUM CUT, M BOARD FEET                 2.0         30.0           .0           .0

                 MINIMUM CUT, 100 CUBIC FEET               3.5          3.5           .0           .0

                 THINNING INTERVAL, YEARS                  7.0         30.0           .0           .0

                 AGE AT FIRST REGEN CUT, YEARS            70.0         30.0           .0           .0

                 AGE AT SECOND REGEN CUT, YEARS             .0           .0           .0           .0

                 AGE AT THIRD REGEN CUT, YEARS              .0           .0           .0           .0

                 AGE AT FIRST PRESC. BURN, YEARS          22.0         30.0           .0           .0

                 PRESCRIBED BURNING INTERVAL, YEARS        7.0         30.0           .0           .0

                 TOTAL ARFA, ACRES                      3249.8       3569.2           .0           .0
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                                          CONDITIONS AT START OF SIMULATION

                                                       PAGE 2
                                                                                         TOTAL AREA OF UNIT-  6819.0
UNIT- BOWIE TRACT.

SIMULATION SITUATION- TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.


INITIAL COSTS OF OPERATIONS, PER ACRE-                                         ANNUAL INCREASES, IN PERCENT-

     PLANTING            80.00                                                     COSTS       3.00

     THINNING            41.00                                                     VALUES      3.00

     BURNING              7.00

     PER CUNIT CUT        1.36

     PER MBF CUT          2.70

     FIXED COSTS           .80

PERIOD OF USE OF VARIOUS CLASSES OF FOODS

     ACORNS - SEPTEMBER TO FEBRUARY, INCLUSIVE.
     BROWSE LEAVES - YEAR-LONG USE.
     BROWSE TWIGS - MARCH TO MAY, INCLUSIVE.
     FORBS - MARCH TO OCTOBER, INCLUSIVE.
     GRASS AND GRASS-LIKE - DECEMBER TO MAY, INCLUSIVE.
     MUSHROOMS - YEAR-LONG USE.
     SOFT MAST - JUNE TO FEBRUARY, INCLUSIVE.
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                                        CONDITIONS AT END OF EACH YEAR

                                                   PAGE  1

      UNIT- BOWIE TRACT.                                                                  TOTAL AREA OF UNIT-  6819.0

      SIMULATION SITUATION- TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

                                    STATUS OF DEER FOODS IN YEAR  1 OF THE SIMULATION

PERIOD ----------------DEER DAYS OF USE PER ACRE---------------   ---------------------ACRES PER DEER---------------------
  OF     DIGESTIBLE     CRUDE                        GROSS         DIGESTIBLE     CRUDE                          GROSS
 YEAR    DRY MATTER    PROTEIN     PHOSPHORUS       ENERGY         DRY MATTER    PROTEIN     PHOSPHORUS         ENERGY

   1        13.4         10.8          4.5           31.2              2.3          2.9          6.8              1.0
   2        10.1          7.9          3.3           21.8              2.8          3.6          8.5              1.3
   3        32.4         27.2         17.6           26.3              1.0          1.1          1.8              1.2
   4        20.0         16.8         10.6           16.5              1.5          1.8          2.8              1.8
   5        39.8         33.7         21.3           32.9               .8           .9          1.5               .9

   6        24.2         13.2          6.4           24.0              1.2          2.3          4.7              1.2
   7        32.2         17.6          8.5           32.0              1.0          1.8          3.6              1.0
   8        40.2         22.0         10.6           40.0               .8          1.4          2.9               .8
   9        42.8         23.8         10.9           48.9               .7          1.3          2.8               .6
  10        45.9         25.6         11.8           53.8               .7          1.2          2.6               .6

  11        30.3         19.7          9.1           44.3              1.0          1.5          3.3               .7
  12        16.3         13.1          5.5           37.6              1.9          2.4          5.6               .8
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                                      CONDITIONS AT END OF EACH YEAR

                                                 PAGE 10

      UNIT= MENIF TRACT                                                                  TOTAL AREA OF UNIT=  6819.0

      SIMULATION SITUATION  TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

                                   STATUS OF DEER FOODS IN YEAR 10 OF THE SIMULATION

PERIOD  ------------------DEER DAYS OF USE PER ACRE----------------   ----------------------ACRES PER DEER----------------------
  OF       DIGESTIBLE      CRUDE                       GROSS          DIGESTIBLE       CRUDE                          GROSS
 YEAR      DRY MATTER     PROTEIN      PHOSPHORUS      ENERGY         DRY MATTER      PROTEIN       PHOSPHORUS        ENERGY

   1          10.9          13.3           5.6           37.1             1.8            2.3            5.5              .8
   2          13.2          10.0           4.2           26.4             2.1            2.8            6.7             1.1
   3          53.2          41.4          28.2           41.6              .6             .7            1.1              .7
   4          29.1          24.1          15.2           24.2             1.0            1.2            2.0             1.2
   5          57.1          47.0          29.6           47.3              .5             .7            1.0              .7

   6          34.6          19.0           9.2           34.7              .9            1.6            3.3              .9
   7          45.7          25.0          12.1           45.7              .7            1.2            2.6              .7
   8          56.5          30.9          14.9           56.6              .5            1.0            2.1              .5
   9          59.7          33.0          15.1           68.7              .5             .9            2.0              .4
  10          64.5          35.7          16.4           75.6              .5             .9            1.9              .4

  11          40.2          26.0          12.1           58.8              .7            1.2            2.5              .5
  12          21.7          17.4           7.4           50.0             1.4            1.8            4.2              .6
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                                                    PAGE 11

UNIT- BOWIE TRACT.                                                                    TOTAL AREA OF UNIT-  6819.0

SIMULATION SITUATION- TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

                                                VOLUMES HARVESTED AND VALUES

          -------------------PINES-------------------             ------------------HARDWOODS------------------
YEAR           CU. FT.           MBF           VALUE                      CU. FT.           MBF           VALUE

  1            8617.           2218.         309403.                          0.             0.              0.
  2             362.           1770.         201611.                          0.             0.              0.
  3            8442.            574.         136644.                          0.             0.              0.
  4            3925.              0.          33669.                          0.             0.              0.
  5            4620.           2820.         386752.                          0.             0.              0.

  6            4304.            228.          67971.                          0.             0.              0.
  7            3822.           1815.         272057.                          0.             0.              0.
  8            4099.           1342.         219504.                          0.             0.              0.
  9            3745.            619.         122665.                          0.             0.              0.
 10            4362.           3686.         568897.                          0.             0.              0.


TOTAL         46299.          15071.        2319172.                          0.             0.              0.
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                                        CONDITIONS AT END OF EACH YEAR

                                                  PAGE 12

UNIT- BOWIE TRACT.                                                                         TOTAL AREA OF UNIT-  6819.0

SIMULATION SITUATION- TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

                                        GROWING STOCK VOLUMES, AND VALUES

         --------------------PINES--------------------            -----------------HARDWOODS-----------------
YEAR         CU. FT.          MBF          VALUE                   CU. FT.          MBF          VALUE

  1          55135.          34690.       4214011.                    0.             0.            0.
  2          59709.          34414.       4346412.                    0.             0.            0.
  3          55472.          35551.       4573015.                    0.             0.            0.
  4          55609.          37298.       4919484.                    0.             0.            0.
  5          55238.          35912.       4893705.                    0.             0.            0.

  6          55704.          37169.       5203584.                    0.             0.            0.
  7          56221.          36772.       5312922.                    0.             0.            0.
  8          56228.          37158.       5524104.                    0.             0.            0.
  9          56005.          38571.       5882736.                    0.             0.            0.
 10          55568.          36604.       5774962.                    0.             0.            0.


                                        CONDITIONS AT END OF EACH YEAR

                                                  PAGE 13

UNIT- BOWIE TRACT.                                                                         TOTAL AREA OF UNIT-  6819.0

SIMULATION SITUATION- TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

                 ANNUAL          ANNUAL           NET                VALUE               TOTAL
YEAR              COSTS           GAINS          INCOME          GROWING STOCK         NET WORTH

  1              34507.          309403.         274897.           4214011.            4488907.
  2              45081.          201611.         156529.           4346412.            4502941.
  3              34428.          136644.         102216.           4573015.            4675231.
  4              43933.           33669.         -10264.           4919484.            4909219.
  5              46651.          386752.         340102.           4893705.            5233806.

  6              64876.           67971.           3095.           5203584.            5206678.
  7              43548.          272057.         228509.           5312922.            5541430.
  8              29606.          219504.         189898.           5524104.            5714002.
  9              40919.          122665.          81746.           5882736.            5964481.
 10              57545.          568897.         511352.           5774962.            6286314.


TOTAL           441094.         2319172.        1878077.
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                                 PRESENT WORTH AND RATE EARNED

UNIT- BOWIE TRACT.                                                 TOTAL AREA OF UNIT-  6819.0

SIMULATION SITUATION- TIMBER-DEER RELATIONS ON TRAVIS PLANNING UNIT.

 VALUE OF INITIAL GROWING STOCK--$  4299505.

                                         VALUES DISCOUNTED TO PRESENT (DOLLARS)
 COMPOUND         FUTURE                                  STOCK
   RATE           GROWING           ALL                   PLUS            ALL          NET
 (PERCENT)        STOCK           INCOMES               INCOMES          COSTS        PRESENT
                                                                                       WORTH

    1.0          5228039.         2184613.              7412652.         416965.      2696182.
    1.5          4976129.         2121568.              7097697.         405602.      2392590.
    2.0          4737507.         2061163.              6798670.         394679.      2104486.
    2.5          4511407.         2003262.              6514669.         384175.      1830989.
    3.0          4297124.         1947745.              6244869.         374070.      1571293.
    3.5          4093987.         1894495.              5988482.         364347.      1324630.
    4.0          3901361.         1843400.              5744761.         354987.      1090269.
    4.5          3718690.         1794364.              5513054.         345976.       867573.
    5.0          3545352.         1747272.              5292624.         337295.       655824.
    5.5          3380860.         1702036.              5082896.         328930.       454461.
    6.0          3224725.         1658572.              4883297.         320867.       262924.
    6.5          3076485.         1616793.              4693278.         313094.        80678.
    7.0          2935708.         1576624.              4512332.         305597.       -92771.
    7.5          2801983.         1537986.              4339969.         298365.      -257901.
    8.0          2674929.         1500809.              4175738.         291385.      -415152.
    8.5          2554206.         1465035.              4019241.         284648.      -564913.
    9.0          2439427.         1430584.              3870011.         278142.      -707637.
    9.5          2330295.         1397401.              3727696.         271858.      -843668.
   10.0          2226507.         1365433.              3591940.         265786.      -973352.
   10.5          2127784.         1334623.              3462407.         259918.     -1097017.
   11.0          2033855.         1304921.              3338776.         254245.     -1214975.
   11.5          1944469.         1276277.              3220746.         248759.     -1327518.
   12.0          1859384.         1248645.              3108029.         243453.     -1434929.
   12.5          1778391.         1221986.              3000377.         238319.     -1537448.
   13.0          1701246.         1196248.              2897494.         233350.     -1635362.
   13.5          1627770.         1171396.              2799166.         228540.     -1728879.
   14.0          1557767.         1147391.              2705158.         223881.     -1818228.
   14.5          1491062.         1124198.              2615260.         219369.     -1903614.
   15.0          1427486.         1101784.              2529270.         214997.     -1985232.
   15.5          1366880.         1080116.              2446996.         210760.     -2063270.

   IDENTIFY RATE EARNED AT POINT WHERE NET WORTH EQUALS ZERO.
```

Myers, Clifford A.
1977. Simulating timber and deer food potential in loblolly pine plantations. South. For. Exp. Stn., New Orleans, La. 29 p. (USDA For. Serv. Gen. Tech. Rep. SO-12)

This computer program analyzes both timber and deer food production on managed forests, providing estimates of the number of acres required per deer for each week or month, yearly timber cuts, and current timber growing stock, as well as a cost and return analysis of the timber operation. The program is applicable to loblolly pine plantations in east Texas and Louisiana but can be readily modified for other species or areas.

Additional keywords: Timber management, forest management, simulation, deer habitat potential, wildlife foods, deer management, *Pinus taeda*, *Odocoileus virginianus*.

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Equipment and Supplies
For Collecting, Processing, Storing, and Testing
Forest Tree Seed

U.S. Department of Agriculture
Forest Service General Technical Report SO-13

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SUMMARY

This publication is a directory of information on equipment and supplies used in handling and treating tree seed. Ten classes of equipment are arranged by types. The use of each device is briefly described. Specifications such as size, capacity, or model number are given. Manufacturers' or suppliers' names are listed, and users of the equipment are identified.

ACKNOWLEDGEMENT

The author would like to thank the International Union of Forest Research Organizations Working Party S2.01.06 for their work in gathering the data for this report.

Equipment and Supplies
For Collecting, Processing, Storing, and Testing Forest Tree Seed

compiled by

F. T. BONNER
Southern Forest Experiment Station
Forest Service
U.S. Department of Agriculture

1977

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Equipment and Supplies For Collecting, Processing, Storing, and Testing Forest Tree Seed

BY F. T. BONNER

INTRODUCTION

This survey of tree seed equipment is the result of a work project of IUFRO Working Party S2.01.06, Seed Problems, which was planned at a symposium on seed processing at Bergen, Norway, in September 1973. Questionnaires were mailed to all members of the Working Party, and replies were organized into the following classes of equipment:

Cone, Fruit, and Seed Collection Equipment
Cone Kilns, Other Extraction Devices
Cleaning/Processing Equipment
Mixing and Sampling Equipment
Moisture Testing Equipment
Storage Equipment
Germinators
Seed Counters
X-ray Equipment
Specialized and Miscellaneous Equipment

Some information has been supplied on uses, pecifications and manufacturers, and laboraories that own and use the equipment are listed y a number code. Readers who desire more deailed information may contact the manufacturer r user.

Other catalogs of seed equipment and supplies xist. The most detailed catalog is the excellent Survey of Equipment and Supplies" published y ISTA in 1975, which covers mainly the cleanng and handling of small samples and laboraory testing. The ISTA catalog includes chemicals nd common laboratory items, which are not inuded in this IUFRO catalog. Two catalogs of ee seed and nursery equipment have also been ublished by the U.S. Forest Services' Equipment Development Center in Missoula, Montana. Both of these catalogs primarily cover U.S. manufacturers. (see p. 35).

EXPLANATION OF DIRECTORY

Equipment was grouped into the 10 broad classes listed previously and further grouped into type of equipment (column 1 of the table). For example, the first class is "Cone, Fruit, and Seed Collection Equipment." Type designations are: Hydraulic Devices, Climbing Devices, Devices to Remove Fruits from Trees, and Miscellaneous.

Under column 2, the use of the equipment is briefly described. The letters P (practical use), R (research work), or L (laboratory use) were given to suggest the kind of operation in which the equipment is normally used.

Column 3, specifications, includes as much information about size, capacity, model number, etc. as could be inserted. All values are converted to the metric system, and if other information has been published, a citation is given.

Manufacturer addresses (if known) are given in column 4. Some respondents gave addresses of suppliers, not manufacturers, in their returned questionnaires. In most of these cases, no attempt was made to identify the manufacturer; often a supplier's address is more useful anyway. If the equipment was home-made in local shops and laboratories, the term "local" will appear in this column.

Column 5 lists the users of the equipment. All laboratories or agencies are identified by a number code (see p. 31), which is based on a geographic system used in an earlier Working Party report (Wiersma, 1976).

Cone, Fruit, and Seed Collection Equipment

Type	Use	Specifications	Manufacturer	User
Hydraulic Devices				
Hydraulic platform	collection (P)	Hydra-Ladder Model HL 18-C	Hydra-Ladder, Inc. P. O. Box 472 Higginsville, MO 64037 USA	106
Hydraulic platform	collection (P)	- -	Eidg. Austalt t. d. Furstl. Versuchswesen, CH-8903 Birmeusdorf, Switzerland	362
Hydraulic platform	collection (P)	tractor-mounted	Hymec, Ltd. Örnsköldsvik, Sweden	452
Hydraulic platform	pollination, collection (P)	Trump Giraffe, 1G 40, 15 m high, Truck-mounted	Trump, Ltd. Kelowna, B.C. Canada	153
Hydraulic platform	collection (P)	Girette, self-propelled hydraulic platform, 4.5 m high	Trump, Ltd. Kelowna, B.C. Canada	153
Hydraulic lift	collection (P)	High Ranger tractor-mounted	unknown	104
Hydraulic bucket	collection (L,P,R)	Skyworker 6950, on International 1700 truck	Skyworker Hughes Keenan Div. Coffect Mfg. Co. London Rd. Delaware, OH 43015 USA	105
Climbing Devices				
Tree bicycle	collection (P)	Baumvelo Tree Bicycle	H. Schneebeli & Co. Schaffhauserstr. 307 Zurich 50 Switzerland	390, 360, 702, 802, 362, 322, 703
Ladders	collection (P,R)	Ecole de Nancy	Ateliers Bega Blvd. d'Austrasie 54000-Nancy, France	320, 321
Ladders	photography, collection (R)	Model #5510, Truck-mounted 9 m high, 360° rotation	McCabe-Powers Body Co. St. Louis, MO, USA	102
Ladders	collection (P)	Swedish pipe ladder	SV. Albertsen Havnen DK-3050 Humlebaek, Denmark	400, 390, 702
Ladders	collection (P)	Model TA10, reach to 10 m	Alufort Colombes, France	322
Ladders	collection grafting (P,R)	W1-BE, 3 m base sections 3 m extensions	AB Wikstrand & Berg Mora, Sweden	425, 802
Ladders	collection (P)	- -	Tønsberg Jernindustri Stokke, Norway	425
Ladders	pollination, collection (P)	9 m high, 4 folding platforms	local	700

Type	Use	Specifications	Manufacturer	User
Climbing Devices				
Ladders	collection, pollination (P,R)	see Danbury (1969)	local	800
Ladders	inspection, collection (R)	see Rietveld (1975)	local	101
Ladders	collection (P)	- -	local	703, 704
Ladders	collection	see Asakawa and Fujita (1962)	local	610
Special equipment	collection (L)	Muschter-Tompa	local	581
Climbing spurs	collection (P)	"Foot hooks"	State Seed Extraction Plant Postbox 118 N-2301 Hamar, Norway	400
Climbing spurs	collection	- -	Canadian Forestry Equipment, Ltd. 5489 Royalmount Ave. Montreal, Quebec, Canada	154
Climbing spurs	collection (P)	Czech model	local	425
Climbing spurs	collection (P)	- -	local	620
Safety belts, harness	collection (P)	Pakawa, Ser. No. 24926, Type BS1 III	Barrow Hepburn & Gale, Ltd., P. O. Box 413 Grange Rd., London	425
Safety belts, harness	collection (P)	Rene´ type Harness for mountainering	(?) France	322
Safety belts, harness	collection (P)	Edelrid rock climbing type	(?) Switzerland	425
Safety belts, harness	collection	- -	Canadian Forestry Equipment, Ltd. 5489 Royalmount Ave. Montreal, Quebec, Canada	154
Safety belts, harness	collection (P)	use with Baumvelo Tree Bicycle	local	360
Safety belts, harness	collection (P)	Czech model	local	425
Catapault	projects rope over branches (P)	- -	ArSiMa Lngangstrade 25 Denmark	620
Catapault	collection (P)	- -	local	801
Devices to Remove Fruits from Trees				
Mechanical tree shaker	shake cones from tree (P)	Schaumann Shaker	H. C. Schaumann & Sons DK-5882 Vejstrup, Denmark	400, 425

Type	Use	Specifications	Manufacturer	User
Devices to Remove Fruits from Trees				
Mechanical tree shaker	shake cones from tree (P)	Shockwave	Orchard Machinary Corp. Yuba City, CA 95991 USA	104
Cone rake	removing cones from outer branches (P)	- -	For. Comm. 25, Drumsheugh Gardens Edinburgh 3, U.K.	390
Cone rake	removing cones from outer branches (P,R)	base studded with 2 rows of 5 to 7 cm nails; spacing depends on cone size	local	152
Cone hook	cut cones from branch (P)	includes knife, tube, and bag	Skogsdon, Ltd. Stockholm	452
Cone hook	cut cones from branches (P)	"Felco 3"	(?) Switzerland	801
Cone hook	cut cones from branches (P)	metal bar, looped end, width adjustment	local	800
Cone hook	cut cones from branches (P)	- -	local	704, 620
Pruner	cut off branches	- -	Canadian Forestry Equipment, Ltd. 5489 Royalmount Ave. Montreal, Quebec, Canada	154
Pruner	cut off branches (R,P)	2m handle, parrot-beak	(?) Australia	801
Pruner	cut off branches (R)	Newman heavy-duty trimmer	Newman Mfg. & Sales Co. Kansas City, KS, USA	100
Pruner	cut off branches (R,P)	"Commando" see Hall et al, (1972)	out of business	801
Rifles	shooting off branches (R)	Remington Speedmaster Model 552.22 and Bushnell Scopechief .22, 3X-8X variable scope	Remington Arms, Inc. Ilion, NY, USA Bushnell Optical Co. Dept. 0198, Pasadena, CA 91107, USA	104
Rifles	shooting off branches (R,P)	Sako "Forester", 0.243 with 4 x 81 Pecar scope	Sako, Finland	801
Rifles	shooting off branches (R,P)	Tikka. "Ithaca" 0.243 with 4 x 81 Pecar scope	Tikka, Finland	801
Miscellaneous				
Cone bag	collecting cut cones (P)	- -	local	620
Cone bags	collecting cones	10, 72, and 108 liter capacity	local	154
Vacuum sweeper	collect *Ulmus* off lawns (P)	vacuum pickup, self propelled	Giant Vac. Mfg. Co. South Willington, CT 06265, USA	153

Cone Kilns, Other Extraction Devices

Type	Use	Specifications	Manufacturer	User
Kilns				
Tobacco kiln	drying *Pinus*, *Eucalyptus* (P)	D.800 "Mini;" diesel-fired, electrical fan; 7.5 x 2 m	Delanco (Pty.) Ltd. Box 283, Brits Transvaal, S. Africa	700
Tobacco kiln	drying (P)	9 x 4.8 m or 9 x 6 m: run at 46°C.	local	802
Small electric	drying (R)	300 watt	Mutumi Sci. Inst. Co., Ltd. No. 15, Honcho, Nihonbashi, Chuoo-ku, Tokyo, Japan	610
Small electric	drying (L,R,P)	2 pre-heating chambers; heat control at 4 levels; can run 4 lots of 1 kg at once.	Benno Schilde Maschinenban AG Bad Hersfeld, West Germany (FDR)	360, 362 370
Kiln	drying (P)	Martin, Model 218 Type MAC	Martin Furnace/Eng. Pty. Ltd., 168 Euston Rd., Alexandria Sydney, Australia	801
Kiln	drying	Anhydric 90 x 62 x 61 cm	Blackworse Lare Walthanstow E. London	704
Kiln	drying (L,R)	reversible cross-circulation	Moore Dry Kiln Co. of Canada, Ltd. P. O. Box 68 Brampton, Ontario, Canada (custom-built)	154
Kiln	drying (L,R)	- -	Officine Meccanicge Giuseppe LANDI-Via Aretina n. 50 Florence, Italy	381
Laboratory oven	drying (L,R)	Thelco, Model No. 31543	Fisher Sci. Co., Ltd. 196 W. Third Ave. Vancouver, B.C. VSY 1E9	152
Extractor	drying	Seed Extractor, Model KKA	AB Svenska Flaktfabriken, Stockholm	702
Kiln	drying (P,R)	Ventilatortrocken-Schrauk TU 1	Herens GMBH Hanau, West Germany (FDR)	370
Drawer kiln	drying small lots (P,R)	80 x 98 x 150 cm, wire mesh trays, 1 hl cap.	J. Scott and Co. Ltd. West Silvermills Lane Edinburgh EH 35D (custom-built)	300
Progressive drying tunnel	pre-dry cones (P)	6 x 1.5 x 2.5 m; 24 hl cap.; 20°-40°C.	local	300
Drum kiln	drying (P)	2.4 m long, 0.75 m diam, 8 hl cap.; storage tray above	local	300
Drum kiln	drying (P)	20 m^3 capacity cylinder; 4 HP fans; 20 drums can dry 15 tons of cones in 2 days	local	322

Type	Use	Specifications	Manufacturer	User
Kilns				
Drying cabinet	drying cones and seeds	2 units, 640 kg cap.	local	361
Rotary kiln	drying (L,R)	electric	local	321, 581
Cone kiln	drying (P)	45 kg cap. ERTI	local (For. Res. Inst.)	580
Kiln	drying (P)	direct oil fired; vertical heat diffuser; 24°-93°C.	local	106
Dryer	drying (R)	gas-fired; 8 bu. cap.	local	104
Drying kiln	drying (P,L)	2 electric heaters, 2 fans; 8 cone boxes, 5 kg per box	local	360
Drum kiln	drying *Larix* (P,R)	- -	local	370
Rotating drums	drying (P)	vertical system on 3 floors 20 hl cap.	A/S Hamjern Hamar, Norway (custom-built)	425
Oven	drying (L,R)	600 W electric heater; fan; 89 x 91 x 76 cm; 2 tiers of 11 trays	local	154
Progressive kiln	drying (P)	20 netting boxes, 1.5 hl cap. per box	local	425
Cabinet kiln	drying (P,L,R)	- -	local	425
Internal fan	drying (P,L,R)	trays for cones; 20°-70°C.	local	452
Kiln	drying (P,R)	wire netting trays (see Morandini, 1961)	local	400
Cone dryer	drying extracting (R)	dryer with tumbler	local	610
Drying Sheds, Houses, Rooms				
House	drying (P)	flue-heated building	local	703
Room	drying (P)	custom-made vegetable drying	Ets SEURET 18, rue Thiers Auxonne, France	320
Shed	drying (P)	4.5 x 4.5 x 2 m; gas furnace, fan; wire-bottom trays	local	153
Shed	drying large Amounts (P)	- -	local	362
Shed	drying (P)	15 m X 12 m; wire-bottom trays	local	703

Type	Use	Specifications	Manufacturer	User
Other Devices				
Electric *Larix* mill	tear apart closed cones (L,P)	- -	H. Schneebeli and Co. Schaffhauserstr. 307, Zurich 50 Switzerland	360
Electric *Larix* mill	tear apart closed cones (P)	Condux-Zahnscheiben-Mühle, Type H 35	Oertli and Co. CH-8307 Effretikon, Zurich	362
Drying racks	drying cones (P)	steel, caster rollers, 74 cm wide, 178 cm long, 183 cm high; uses 9 wooden frame trays with screen bottoms	Union Steel Products Albion, MI 49224	106
Extraction tray	drying (P)	plastic covers; uses heat from sun	local	620, 703
Black plastic	drying (R)	black plastic sheets; uses heat from sun	local	100
Storage trays	drying (P)	wooden crates with wire mesh bottoms	local	362
Drying trays	drying (L,R)	wooden sides, 61 x 107 cm wire mesh bottoms	local	154

Cleaning/Processing Equipment

Type	Use	Specifications	Manufacturer	User
Tumblers				
Snoco screen drum	extraction from cones, pods (P)	rotating screen drum	The Snow Co. Omaha, NB 68101 USA	153
Cone tumbler	extraction from cones (P)	- -	A. Doumas Route de Poleymieux Albigny-Su-Saône, France	320
Cone tumbler	extracts seeds (R)	60 cm diameter wire drum turned by motor	local	102
Cone shaker	extracts seeds (P)	conical drum, 3 m long; end diam. 127 and 91 cm; 6 mm mesh screen; turns at 30 rpm	local	106
Tumbler	*Pinus* extraction (P)	assembled on electric concrete mixer	local	801
Tumbler	Small sample extractor (P,R)	square box; hand-turned	local	153
Cone tumbler	extracts seed from cones (P)	barrel 3 m long, 122 cm diam.	local	802
Cone shaker	*Pinus silvestris* *Picea abies* (R)	romboid of metalic net rotates on short axis; capacity 10 ℓ cones	local	450
Screen drum	separates seeds (P)	- -	local	322
Tumbler	extraction of seed (P)	hand-operated; large model progressive; 500 bags of cones/day	local	703
Cone tumbler	extraction of small lots (L,R)	see Harris (1970)	local	152
Cone tumber	extraction from cones (P)	- -	local	700
Cone shaker	extraction from cones (P)	- -	local	154
Dewingers				
Nordmark dewinger	conifer dewinging (P)	Nordmark, sizel, Wolfgang Model	Streckel & Schrader K.G. 2 Hamburg 70 Postfach: 13453 West Germany	321
Nordmark dewinger	conifer dewinging (P)	Nordmark, sizel, Wolfgang Model	Also Landmaschinen AA Bern-Bümplitz-Süd CH-3018 Bern Switzerland	362
Nordmark dewinger	conifer dewinging, large lots (P)	Nordmark, Size 00 Wolfgang Model; 2 kg capacity; some local modifications	Georg Restle Propr. W. Feierabend, Mudhlen-u. Specherbau, Wiesbaden West Germany	360

Type	Use	Specifications	Manufacturer	User
Dewingers				
dewinger	dewing small lots (P,R)	Liliput Model	Streckel & Schrader Hamburg West Germany	370
Crippen dewinger	most conifers (P)	Crippen Dewinger and Aspirator; Model EP-26	Crippen Mfg. Co., Inc. Alma, MI 48801 USA	106
Sharples dewinger	*Abies*, *Larix*, *Pinus*, *Picea* (P)	60 cm Sharples-Kason Virbroscreen	The Sharples Co. Tower Works, Doman Rd. Camberley, Surrey England	300
Concrete mixer	wet dewinging (P)	Lescha VM 140	Leonhard Schmid KG 89 Augsburg West Germany	425*/
Dybvig macerator	any winged seed (L,P,R)	ca. 1 HP electric motor drive	Melvin Dybvig 208 Main Tillamook, OR 97141, USA	100, 153
Clipper debearder	*Fraximus*, *Acer* *Liriodendron* (P)	variable drive unit	Ferrell-Ross Co. 6501 S. Interpace Dr. P. O. Box 26468 Oklahoma City, OK 73126 USA	106
Seed scarifier	dewing small lots (R)	Forsberg Sample Scarifier, electric	FredForsberg & Sons Thief Rivers Falls, MN 56701, USA	100, 106, 153, 600
Vacuum dewinger	dewing *Psendotsuga* (L, R)	Electrolux Vacuum Cleaner	any home appliance outlet	151
Vacuum dewinger	wet dewinging small lots (L,R)	Membranefilter SM 16829 plus vacuum pump	Kebo-Grave Ltd. Stockholm	452
Wet dewinger	small *Pinus* lots (R)	Osterizer "Pulse-Matic"	John Oster Mfg. Co. Milwaukee, WI	100
Brush dewinger	dewing conifers (P)	- -	A. Doumas Route de Poleymieux Albigny-Su-Saône France	320
Vacuum dewinger	wet dewinging small lots (R)	series of small containers tied to vacuum source	local	450
ewinger	dewing conifers (P)	- -	local	322
ewinger	dewing conifers (P)	Mod. Kohmann-Saylund (principle of Prof. Schmidt)	local	425

/ Other concrete mixers used by 100, 452, 154.

Type	Use	Specifications	Manufacturer	User
Depulpers				
Dybvig macerator	depulp fleshy fruits (P,L,R)	ca. 1 HP electric motor drive	Melvin Dybvig 208 Main Tillamook, OR 97141, USA	100, 106, 153
Blender	depulp small lots (R)	Osterizer "Pulse-Matic"	John Oster Mfg. Co. Milwaukee, WI	100
Blender	depulp small lots (R)	Wareing Model PB 5A	Wareing Products Corp.	153
Cone Cleaners				
Cone grader	cleans cones (P)	"Amazone", Model FOK, 3/4 HP motor	Landmaschinen AG Bern-Bümplitz-Süd CH-3018 Bern Switzerland	362
Cone cleaner	cleans cone lots (P)	Sherwen High Resonance, screens 0.6 x 1.2 m	Fraser & Chalmers Engine Works Erith, Kent England	300
Screen Cleaners				
Vibration sieves	separates seed from scales (P)	Vibrationssiebmaschine Varius, 600/1200/2	Condux-Werke Wolfgang bei Hanan, West Germany	362
Clipper cleaner	cleaning, sizing (L,R,P)	Clipper office tester; screens 25 X 38 cm	Ferrell-Ross Co. 6501 S. Interpace Dr. P. O. Box 26468 Oklahoma City, OK 73126, USA	100, 102, 106, 153, 154
Clipper cleaner	cleaning, sizing (P)	Clipper M2B	Ferrell-Ross Co. (see above)	153
Clipper cleaner	cleaning sizing (P)	Clipper No. 27	Ferrell-Ross Co. (see above)	106
Seed cleaner	cleaning, sizing (P)	Burrows Vac-a-Way, No. 30	Burrows Equip. Co. 1316 N. Sherman Ave. Evanston, IL 60201 USA	801
Cleaner/grader	cleans small lots (P,L)	Minipetkus, Model C	Röber Saatreiniger O.H.G.I. 495 Minden Westfallen 2 West Germany	321
Scalper	removes large trash (P)	Speed Scalper, Model 3651	Seedburo Equip. Co. 618 W. Jackson Blvd. Chicago, IL 60606 USA	106
Seed cleaner	cleaning, sizing (P)	2-screen model, with fan	Robert Boby Ltd. Bury St. Edmunds, Suffolk, England	300
Seed cleaner	cleaning (P,R)	Wiljak Model	W. Jäger Königswinter, West Germany	370
Seed cleaner	scalping (P)	CFC 54	Maskinfabriken CFC Strib, Denmark	425

Type	Use	Specifications	Manufacturer	User
Screen Cleaners				
Seed cleaner	cleaning, sizing (P)	LA-LS	Kamas, Kvarnmaskiner AB, Fack, S-200 42 Malmo 7, Sweden	452
Seed cleaner	cleaning, sizing (P)	Petkus I, with size 4 dust control	Landmaschinen AG Bern-Bümplitz-Süd CH-3018 Bern Switzerland	362
Scalper	removes large trash (P)	- -	A. Doumas Route de Poleymieux Albigny-sur-Srône, France	320
Seed cleaner	cleans small lots (L,R)	QB-123	Labor Instrument Works 1450 Budapest, P.O. B. 33 Hungary	580
Needler	removes needles, flat trash (P)	- -	local	106
Seed cleaner	cleans lots (P)	38 cm Fan, collection boxes	local	703
Seed cleaners	cleaning, sizing (P)	- -	local	322
Sieves, Screens				
Shaking sieves	cleaning, sizing, (P,R)	MK II, holds 10 sieves	Endecotts (Test Sieves) Ltd. London SW 19 England	152, 300
Shaking sieves	cleaning, sizing (R)	Test Sieve Jel 200	Gallenkamp P. O. Box 290 Technico House Christopher Str. London E.C. 2 England	701
haking sieves	cleaning, sizing (P,R)	FOK 401	A. Baumüller Marktredwitz West Germany	370
and screens	cleaning *Eucalyptus* (L,R,P)	wire cloth, rectangular holes	Ferrell-Ross Co. 6501 S. Interpace Dr. P. O. Box 26468 Oklahoma City, OK 73126, USA	105
and sieves	cleaning, sizing (R,P)	Greenburn Brass Lab. sieves, B.S.S. standards	Greer & Ashburner Pty., Ltd. 85 Cremorne Str. Richmond, Vic. 3121 Australia	801
and screens	sizing (L,R)	44 hole sizes 663-1681-1	Polikeit, Halle East Germany	581
and sieves	cleaning (P)	made from palm leaves	local	704

Type	Use	Specifications	Manufacturer	User
Pneumatic Cleaners				
Pneumatic separator	cleaning *Pinus* (P)	Mandrel ESM, 2 1/2 HP, Dry Product Model	Mandrel Products 6909 SW Freeway Box 36306 Houston, TX 77036 USA	700
South Dakota blower	cleaning small lots (L,R)	Models A, B	E. L. Erickson Prod. Brookings, S.D. 57006, USA	151, 153
South Dakota blower	cleaning small lots (L,R)	Model D	E. L. Erickson (see above)	104, 300, 400
South Dakota blower	cleaning small lots, or *Eucalyptus* (L,R)	Model 1836-3 (small blower for *Eucalyptus*	Burrows Equip. Co. 1316 Sherman Ave. Evanston, IL 60201 USA	105, 801
Seed blower	separate full & empty clean *Eucalyptus* (L,R)	Model ER General Seed Blower	Seedburo Equip. Co. 618 W. Jackson Blvd. Chicago, IL 60606 USA	100, 600
Seed aspirator	clean small lots (R)	Funnel 23 cm diam., 51 cm tall	Precision Machine Co. Lincoln, NB USA	102
Seed aspirator	clean small lots (L,R)	200 g capacity	Craftsman Machine Co. 201 Princess St. Winnipeg, Man. Canada	154
Air cleaner	clean small lots (L,P)	Nordströms Blästerapparat	AB G. L. Jacoby Stockholm, Sweden	425
Seed cleaner	clean small lots (R)	2-stage aspirator	Lindner & May Brisbane, Australia (custom-made)	802
Winnower	clean light trash (P)	office fan	any commercial make	802
Fanning mill	cleaning (P)	- -	A. Doumas Route de Poleymieux Albigny-sur-Saône	320
Seed blower	cleaning small lots *Pinus*, *Abies*	"Silen-type", with modifications (see Wollard & Silen, 1973)	local	152, 450
Seed blower	cleaning *Betula* (R)	(see Bjorkroth, 1972)	local	450
Seed cleaner	cleaning small seeds (L,R)	vertical air column	local	452
Seed cleaner	cleaning small lots (R)	air separation	local	340
Seed cleaner	extract and clean *Populus* (R,L)	compressed air blows seed through wire mesh	local	154

Type	Use	Specifications	Manufacturer	User
Gravity Separators				
separator	cleaning (P)	Latka 34-B	Damas DK-5764 Vester, Aby, Denmark	620, 700
separator	cleaning (P)	Damas Type TRYLU 125-B	Damas (see above)	400, 425
separator	grading, separating (R)	Damas Type Lakas and Latka Lab model	Damas (see above)	801
densimetric grader	grader (P,L)	"Vibragen" Model	SOCAM 7 Blvd. Jean Jaures 28000-Chartres France	321
gravity table	sizing removing empties (P)	Model 10M2	Fred Forsberg & Sons Thief River Falls, MN 56701, USA	106
gravity table	sizing grading (P)	- -	Oliver Mfg. Co., Inc. P. O. Box 512 Rockyford, CO 81067, USA	322
gravity separator	grading large lots (P)	LA-K	Kamas Kvarnmaskiner AB Fack, S-200 42 Malmo 7, Sweden	452
gravity separator	cleaning, grading (P,R)	Model V135	Triple/S Dynamics Sutton/Overstrom, Inc. 1029 S. Haskell Dallas, TX 75223 USA	100, 300
lail-shaker	cleaning (P)	trash and wings separated on shaking tray	local	802
lotation Separators				
eed cleaner	remove empty *P. sylvestris* and *Picea abies* (R)	flotation in alcohol, small smaples only (see Simak, 1973)	local	450
eed cleaner	remove empty and damaged *Betula* seeds (R)	flotation in carbon tetrachloride/hexane (see Bjorkroth, 1973)	local	450
rying Equipment				
eed drier	reduce moisture content (P)	forced draft, 30°-40°C; cap. 9 x 5 kg *Abies*	local (Natl. Inst. Agr. Eng., Wrest Park, Silsoe, Bedford, England)	300

Mixing and Sampling Equipment

Type	Use	Specifications	Manufacturer	User
Mixers, Dividers				
Divider	mix and sample (R,P)	Boerner Divider (inverted cone type)	Burrows Equip. Co. 1316 Sherman Ave. Evanston, IL 60201 USA	100, 106, 425, 801, 154
Divider	mix and sample (R,P)	Gamet Precision Divider, (electric)	Dean Gamet Mfg. Co. 6427 Penn Ave. Minneapolis, MN 55440, USA	100, 801
Divider	mix and sample (P)	QB-105	Labor Instrument Works 1450 Budapest, P.O. B. 33 Hungary	580
Divider	mix and sample (L)	- -	Mahesh Agro Industrial and Auto Engg. Corp. 13-A/39 WEA. Pusa Rd. New Delhi-5, India	600
Mixer	mix for uniformity (P)	100 ℓ and 120 ℓcap. CFC 87-3, CFC 254-1	Maskinfabriken CFC Strib, Denmark	425
Mixer	mix for uniformity (P)	1000 kg cap. (*Picea*)	Carier East Street Braintree, Essex England	300
Mini-Seed Divider	mix and sample (L)	hooper 12 x 8.5 cm, cardboard	local	425
Divider	mix and sample (L)	like cups method	local	380
Drying Equipment				
Seed drier	dry small lots after wet dewinging (P)	standard fan	Sv. Fläktfabr. Ltd.	452
Seed drier	dry after wet dewinging (P)	revolving drum, 1.4 m long, 38 cm diam.; 2 kw heat	local	300
Seed drier	reduce moisture before storage (P)	electric heat, 2 sections	local	425
Seed drier	reduce moisture (P)	- -	Dydra St. Mammes, France	322

Type	Use	Specifications	Manufacturer	User
Miscellaneous Equipment				
Syntron vibratory Feeder	maintain even flow rate into cleaners (P)	Model FTOB, 5 x 25 cm trough; Model FT01, 10 x 46 cm trough	FMC Corp. Syntron Div. 1938 Black St. Homer City, PA 15748 USA	300
Color separator	grading (P)	Sortex	Gunsons Sortex Ltd. London, England	322
Dust exhaust	remove dust from cleaning machines (P)	Entstäubungsapparat R 300/1200	Munster Fabrik Für Luft-und Wärmetechnische Apparate CH-4132, Muttenz Switzerland	362
Triers, Samplers				
Trier, sleeve-type	pull samples (P,L)	Burrows No. 518, 46 cm	Burrows Equipment Co. 1316 North Sherman Ave. Evanston, IL 60201 USA	425
Sampling stick	pull samples (P)	86 cm long, 3 compartments	Bryan Corcoran, Ltd. London, England	300
Double-tube trier	pull samples (P,L)	64 cm long	local	425
Sample splitter	reduce size of sample (P)	- -	local	300
Cone, Fruit Cutters				
Seed cutter	viability estimation (L)	QB-127	Labor Instrument Works 1450 Budapest, P.O. B. 33 Hungary	580
Cone cutter	longitudinal slicing, (P,L,R)		local	425
Cone knife	longitudinal slicing (P)	25 cm pivoted blade, adjustable	local	300
Acorn/cherry cutter	viability est. (L,P)	knives mounted on steel base, pivoted on blade end	local	106
Seed Analysis Boards				
Purity work board and diaphano scope	purity analyses (L)	stainless steel, center section opal glass	Seedburo Equipment Co. 1022 W. Jackson Blvd. Chicago, IL 60607 USA	600
Seed analysis table	all seed analyses	QB-134	Labor Instrument Works 1450 Budapest, P. O. B. 33 Hungary	580

Moisture Testing Equipment

Type	Use	Specifications	Manufacturer	User
Gravimetric Testers Which Dry Seeds				
Brabender oven	seeds and cones (P,F,R)	resistance heaters dry seeds; scale read-out in % moisture	Brabender O.H. Duisburg, West Germany (FDR)	360, 370, 425, 381
Infra-red drier	seeds (P,L)	"Infradior" Model	V. Buys 59175 Templemars/esllile France	320, 321
Infra-red drier	seeds (L,R)	"Ultra-Duplex"; 2 IR heat bulbs dry seeds; scale read-out in % moisture	A. Gronert 4914 Kachtenhausen Lippe West Germany (FDR)	360
Infra-red drier	seeds (R,P)	Ohaus Model C 6000; 10 g samples	Ohaus Scale Corp. 1050 Commerce Ave. Union, NJ 07083 USA	106, 153
Infra-red drier	seeds	A.S.E. Balance, No. 719; 250 W.	A.S.E. Palmtag West Germany	300
Infra-red drier	cones in field	X-14 Agat; 150 W	AB G. L. Jacoby Stockholm Sweden	425
Infra-red drier	seeds (P,L,R)	Mettler LP 12	Mettler Instruments, Ltd. Zürich, Switzerland	802
Infra-red drier	seeds (P,L)	"Ultramat"; 1IR bulb, scale read-out in % moisture	Carl Bittmann Wissenschaftl. Forschungs-Instr. CH-4003 Basel, Switzerland	362
Electric Meters, Indirect Measure				
Electric meters	seeds (P,L,R)	Burrows 400 (also Dole 400); portable (formerly Radson meter)	Burrows Equipment Co. 1316 N. Sherman Ave. Evanston, IL 60201 USA	100, 104 300, 700, 701
Electric meter	seeds (P,L,R)	Super-Beha	N. Foss Electric 39 Roskildevej DK-3400 Hillerod, Denmark	400, 401, 620, 702, 801, 802
Electric meter	seeds (L,R)	Model 400-G	Seedburro Equipment Co. 618 W. Jackson Blvd. Chicago, IL 60606 USA	380, 600
Electric meter	cones and seeds (P)	Klein Feuchtemesser Type 2122	Fabrik Elektro-Physikalischer Geräte Karl Weiss KG Greiz, West Germany (FDR)	425
Electric meter	seeds (L,R)	Motomco Model 919	Motomco, Inc. Patterson, NJ 07513 USA	100

Type	Use	Specifications	Manufacturer	User
Direct Moisture Determinations				
Karl Fischer apparatus	(R)	Karl Fischer Tritator E551	Metrohm AG CH-9100 Herisau, Switzerland	380
Karl Fischer apparatus	(R)	Precision Auto-Aquatrator Model 68830	Precision Scientific Co. Chicago, IL 60680 USA	100
Brown-Duvel tester	(L,R)	electric distillation, 1- or 2-sample models	Seedburro Equip. Co. 618 W. Jackson Blvd. Chicago, IL 60606 USA	600
Toluene distillation apparatus	(L,R)	Bidwell/Sterling, Dean/Stark glassware (see Hart and Golumbic, 1963; Buszewicz, 1962)	any laboratory glassware supplier (see ISTA catalog)	100, 152 380, 425, 801
Marcuson distiller	(L,R)	"Di Marcuson"	Ditta Prokeme via G. Fabroni 48/R Firenze Italy	381
rying Ovens				
ven	drying seeds, fruits (L,R)	Model 125A or 125B	Tempo Ind. Corp. Bombay-57 India	600
ven	drying seeds, fruits (L,P)	Model EM 10	M. Chopin and Co. S.A.R.L. 5, Rue Escundier 92100-Boulogne Billancourt, France	320, 321, 322
ven	drying seeds (R)	Temp. range 0°-200° C	Burchi and Tuci Florence, Italy	380
ven	drying seeds (L)	Heraeus Type RT 360	W. C. Heraeus GMBH Hanau, West Germany (FDR)	425
ven	drying seeds (L,R)	- -	Polikeit Halle, East Germany (GDR)	581
en	drying seeds (P,R)	Qualtex Model 71 range 0°-200°C.	Watson Victor, 95-99 Epping Rd. North Ryde, N.S.W. 2113, Australia	801
en	drying seeds (L)	OV 300, Size 1	Gallenkamp & Co., Ltd. Technical House Christopher Str. London EC2P	300
en	drying seeds (P,L)	Thermo Circulator, 0°-200°C.	Labline Instr. Labline Plaza 15th & Bloomingdale Ave. Melrose Park, IL 60160 USA	106

Type	Use	Specifications	Manufacturer	User
Miscellaneous				
Hygroscope cards	indicate moisture in storage drums (P)	TL 6685 003 A1	Dydra St. Mammes, France	322

Storage Equipment

Type	Use	Specifications	Manufacturer	User
Walk-in Units				
Refr. room	storage (R)	2.4 x 2.4 x 2.4 m -10° and +4°C.	Windman Co. St. Paul, MN USA	102
Refr. room	storage (P)	Therma-Kühlmaschine Typ. WH4F90 +3° and -5°C.	Therma, Kältebüro Zurich, CH-8042 Switzerland	362
Refr. room	long-time storage (P)	Climatfroid (Satam) 80 m^3°; -18° to -40°C.	Climatfroid (Satam) France	322
Refr. room	storage (P)	4.4 x 2.2 x 3 m + 2-3°C.	Therma, Kälte und Klima CH-8000 Zurich, Switzerland	360
Refr. room	storage (P,R)	various sizes, built into building	Carrier Corp. Syracuse, NY USA (refrigeration)	152
Refr. room	short storage for high-moisture seeds (P)	Neve 80 m^3, +7°C.	Neve Satam France	322
Refr. room	medium to long storage (P)	Neve, 100 m^3, +1°C.	Neve Satam France	322
Refr. room	storage (P,R,L)	0° to 5°C. no humidity control	local	106, 340, 620, 700 703, 801, 802
Refr. room	storage (P)	+1 to 3°C., 30-35% real humidity; 50,000 kg capacity	local	425
Refr. room	storage (R)	2° to 4°C., 35-45% rel. humidity; 3 x 6 x 2m	local	100
Refr. room	storage (P)	-9° to -7°C., 20,000 kg capacity	local	425
Refr. room	storage	-12°C.	local	104
Reach-In Units				
Refrigerator	storage	Frigomatic FWF-165	Autofrigor SA CH-8000 Zurich Switzerland	361
Refrigerator	storage, prechill (L,R)	Electrolux RF 70/14; -22° to +7°C.	Electrolux Svenska Forsaljnings Ab. Stortorget 17 S-211 22, Malmo Sweden	380
Refrigerator	storage (P)	Dayton 1 OHFO	Frigidaire Div. General Motors Corp. USA (widely available)	704
Refrigerator	storage, prechill (L)	KPS Type k-211, extra thermostat	K. Pettersen and Sonner Norway	425

Type	Use	Specifications	Manufacturer	User
Reach-in Units				
Refrigerator	storage, prechill (R,L)	Kelvinator Model 266	M/S Kelvinator of India, Ltd. 19-A Alipore Rd. Delhi-6 India	600
Refrigerator	storage	VYROBC 8999 420 kg capacity	Czechoslovakia	704
Refrigerator	storage (L,R)	- -	various models of local purchase	100, 151, 802
Freezer	storage (R)	Hitachi, Model RC8521 (0°); Model RC2402L (-20°C.)	Hitachi Electronics Co., Ltd., 23-2, Ichome Kanda-Sudacho Chiyoda-ku Tokyo, Japan	610
Freezer	storage (L,P,R)	Bosch GS 530, -25°C.	Robert Bosch AG Diesel u. Electric 8021 Zurich Switzerland	360
Freezer	storage (P,R)	Astor; temp. below 0°C.	Astor Italy	801
Freezer	long storage (L,P)	ITT Type HF-53	Standard Telefon-og Kabelfabrik Oslo, Norway	425
Freezer	storage (R)	two units, -20° and -2°C.	Sv. Fläktfabr. Ltd. Sweden	452
Freezer	storage (L)	Kelvinator Model 275	M/S Kelvinator of India, Ltd. 19-A Alipore Rd. Delhi-6, India	600
Freezer	storage	-10° to 0°C.	Commercial Cold Store Rogers, Brisbane Australia	802
Containers				
Drums	storage (R)	Leverpak Fiber Drums 61 cm diam, 61 or 91 cm tall	Continental Can Co. New York, NY USA	104
Drums	storage	30 liter polyethylene drums - "World Star"	Manser KG Skoln-Ehrenfeld 1 (RFA) France	320
Cans	storage (P)	36 x 23 x 23 cm; 10 kg capacity of *Pinus* or *Picea*	Metal Box Co. England	300
Plastic bags	storage (R)	Whirl-Pak	Nasco Ft. Atkinson, Wisc. 53538 USA	104
Tubes	storage (R)	coin tubes, Model 1005	Security Tubes Midwest Plastics, Inc. Wichita, KN, USA	105
Bottles	storage (P,L,R)	1/2 and 1 liter capacity, rubber ring seal; can vaccum-seal	Glashütte CH-8180, Bulach Switzerland	360

Type	Use	Specifications	Manufacturer	User
Containers				
Miscellaneous bags, bottles, cans	storage (P,L,R)	- -	various local retail sources	100, 362, 390, 704
Miscellaneous				
Shelving	support containers (P)	Dexion modular	Dexion G.M.B.H. 6312 Laubach Hessl, Dexion Strass, 1-5, West Germany (FDR)	801
Dehumidifier	removes moisture from storage room	Model No. 150	From Crown Agency	704
Plastic bag sealer	seals poly bags (P,L)	Impuls-Schweisspress, Impress 400 DV, No. 613	Ampack AG Rorschach CH-9000 Rorschach, Switzerland	362

Germinators

Type	Use	Specifications	Manufacturer	User
Jacobsen Type				
Copenhagen tanks	testing	220 V	Charles Hearson Co., Ltd. 172 Brown Hill Rd. Catford, London SE6 England	704
Copenhagen tank	testing	- -	Grant Instruments Ltd. Barrington, Cambridge England	620
Jacobsen tank	testing (L,R)	- -	Burchi and Tuci via A. Giannotti n.15 Florence, Italy	381
Jacobsen table	testing (L,R)	5 tables, modified from Løken (1968)	local	425
Copenhagen tank	testing (P,R)	300 x 55 cm (large) 60 x 51 cm (small)	local	300
Jacobsen system	testing (L,P,R)	- -	local	322, 370 581, 620
Jacobsen apparatus	testing (L,R)	15° to 50°C.; flourescent lights	local	380
Germination table	testing (L,R)	"Løken type" (see Løken, 1968)	local	452
Germination apparatus	testing	2 tables (see Løken, 1968; Alfjorden, 1973)	local	450
Germination tank	testing (L,R)	trays 12.5 cm wide; "Blue-M" water bath	local bath: Blue-M Electric Co. Blue Island, IL 60406 USA	152
Germination pans	testing (L,R)	similar to above, but 8 cm deep pans; all in contr. temp. room	local	152
Jacobsen germination	testing *Abies*, *Cedrus* (P)	Jacobsen cups, some UV light	local	322
Cabinet Germinators				
Electric	testing (R)	70 x 90 x 70 cm	Satoo Scientific Instr. Co., Ltd. Japan	610
Electric	testing (R)	70 x 90 x 150 cm	Kyoshin Sci. Instr. Co., Ltd. Bunkyo-ku Tokyo, Japan	610
Catalina	testing (R)	Isuzu Catalina SLV-12D, and Model SLV-4E	Isuzu Instr. Co., ltd. 3-8-19, Nishi-Ochiai, Shinjuku-ku, Tokyo, Japan	610
Conviron	testing (P,L,R)	Conviron G30; 4° to 40°C.; automatic, 8 trays	Controlled Environment 661 Madison Str. Winnipeg 21, Manitoba Canada	150, 152, 360, 154

Type	Use	Specifications	Manufacturer	User
Cabinet Germinators				
Seedburo	testing	- -	Cleland Mfg. Co. 2800 Washington Ave. Minneapolis, MN 55411, USA	100, 153 700
Pfeiffer	testing (L,P)	Daylight Germinator Model LC-DL with recording device	J. P. Pfeiffer & Son 1817 B Whitehead Rd. Baltimore, MD 21207	106
Stults	testing (L,P)	Da-Lite, Junior Model	Stults Scientific Engineering Corp. 3313 S. 66 Freeway Springfield, IL 62703 USA	100, 106 600
Linder and May	testing (P)	0° to 40°C. (several models)	Lindner and May 243 Lutwyche Ave. Windsor Brisbane, Australia	801, 802
Steinmetz	testing (L,R)	modified Steinmetz cabinet	Steinmetz Apparatebau D-8 München 15 Postfach 103 West Germany (FDR)	381
Freas	testing (L,R)	Freas low temp. 815; -10° to 50°C	Precision Sci. Co. 3737 W. Cortland Str. Chicago, IL 60647 USA	380
Precision	testing (L,R)	"Precision" low temp. 31213; 5° to 50°C.	Precision Sci. Co. (see above)	380
Incubator	testing	Precision Incubator Model 805; 5° to 50°C.	Precision Sci. Co. (see above)	620
Bertagnin	testing (L,R)	Bertagnin 500, -10° to 50°C.; up to 90% rel. humidity	F. illi Bertagnin Bologna, Italy	322, 380
Low temp. cabinet	testing (L,R)	Automat Super-10	Scientific Equipment Works Nicholson Rd. Delhi, India	600
Germinator	testing	5° to 30°C.	Plastina Zone Industrielle Heillecourt-Est 54044-Nancy Cedex France	320
rant automatic	testing	Use in room at least 2°C.	Grant Instruments Ltd. Barrington, Cambridge England	620
odewald	testing (P,L)	tub with sandy substrate, irrigated from below; 90 x 60 cm	Steinmetz Apparatebau D-8 Munchen 15 Postfach 103 West Germany (FDR)	362, 703
ab-Line	testing (R)	temp. and light control	Lab-Line Instruments Melrose Park, IL 60160 USA	105
abmaster	testing (P)	10° to 40°C.	? USA	802
rminator	testing	QB-117/2	Labor Instrument Works 1450 Budapest, P.O. B. 33 Hungary	580

Type	Use	Specifications	Manufacturer	User
Cabinet Germinators				
Germinator	testing in sand (R)	(see Gustafsson and Simak, 1958)	local	450
Germinator	testing (L,R)	- -	local	321, 390, 600, 800
Incubator	testing (P,R)	large and small units for sand and TP tests	local	300
Germination Rooms				
Growth chamber	testing, seedling growth (L,R)	Conviron 7 D3A3	Controlled Environment 661 Madison Str. Winnipeg 21, Manitoba Canada	153
Phytotron	seedling growth (R)	6 rooms with different temperature regimes 6 rooms with different temperature, light, and humid regimes 1 room with different temperature regimes and different light quality	local	610
Phytotron	testing (R)	8 rooms with different temperature and light regimes combined with 20 growth chambers	local	340
Walk-in	testing	- -	local	600
Thermogradient Plates				
Thermogradient plate	testing (R)	gradient 10° to 40°C.; surface 120 x 66 cm	local	300
Thermogradient apparatus	testing (R)	tests great range of temperature at one time	local	801
Thermogradient apparatus	testing (R)	2-way gradient; 10° to 40°C.; surface 76 x 76 cm	local	100

Seed Counters

Type	Use	Specifications	Manufacturer	User
Electronic Counters				
Syntron	seed counts (R,L,P)	I.C.A.L. Ref. y-12994	Syntron Division Int. Combustion Australia, Ltd., South Str. Rydalmers N.S.W. Australia	801
Syntron	seed counts (R,L,P)	Model EB-00 240V, 60 cy.	Syntron (see above)	800
Asco	seed counts (R)	Model 2080	Agr. Specialty Co., Inc. 11313 Frederick Ave. Beltsville, MD 20705 USA	100
Seed counter	seed counts (R)	Model GEP	Tripette et Renaud Paris, France	322, 340
Seed counter	seed counts (R)	QB-133	Labor Instrument Works 1450 Budapest, P.O. B. 33 Hungary	580
Seedburo	seed counts (R)	Count-A-Pak Model 88 (modified)	Seedburo Equipment Co. 618 W. Jackson Blvd. Chicago, IL 60606 USA	104
Seed counter	seed counts (L,R)	photoelectric	Audiotronics 37 Hopewell Ave. Ottawa, Ontario Canada	
acuum Counters				
ounter head	seed placement (R,P)	round, chromed heads, various sizes	G. L. Jacoby Lastmarkergaten 27B, Stockholm C Sweden	425, 801
mes	seed counts, seed placement (R,L)	Ames Model 3, various heads	E. L. Erickson Prod. Brookings, S.D. 57006 USA	100, 106 153, 154
acuum counter	seed counts (R)	100-hole vacuum head	Lindner and May Brisbane, Australia	802
neumatic counter	seed counts (L,R)	Omega model	Polikeit Halle, East Germany (GDR)	581
neumatic counter	seed counts, seed placement (R,L)	QB-101/1	Labor Instrument Works 1450 Budapest, P.O. B. 33 Hungary	580
cuum counter	seed counts, seed placement (P,L,R)	modified household cleaner	Firma Max Müller Feinmech-Werkstätten CH-8910 Affoltern a. Albis Switzerland	360
sten Vacuum Tweezers	seed placement (R)	Dymax MK1, various sizes (biased to empty seeds)	Charles Austen Pumps, Ltd. Petersham Works 100 Roysten Rd. ByFleet, Surrey England	300

Type	Use	Specifications	Manufacturer	User
Vacuum Counters				
Vacuum counter	seed counts (L,R)	- -	local	380
Vacuum counter	seed placement (L)	100 holes in head	local	322
Counting Boards				
Laboratory counters	seed counts (L)	Ser. No. 66660 A, 69996 (5 and 8 keys)	Clay Adams, Inc. New York USA	425
Counting boards	seed placement (R)	Erickson boards, Nos. 1, 2, & 5	E. L. Erickson Prod. Brookings, S.D. 57006 USA	100
Counting plates	seed counts (L,R)	- -	local	600
Sampling boards	seed counts (R)	made for *P. abies*, *P. sylvestris* (see Tifen, 1949)	local	450
Counting plates	seed counts (L)	100 holes per plate, 7 sizes	local	322
Other Devices				
Vibrating spoons	seed counts (L,R)	Mettler Vibro-Spatula LV 2 (4 models)	Mettler Instruments CH-8606 Greifensee Switzerland	425, 801

X-ray Equipment

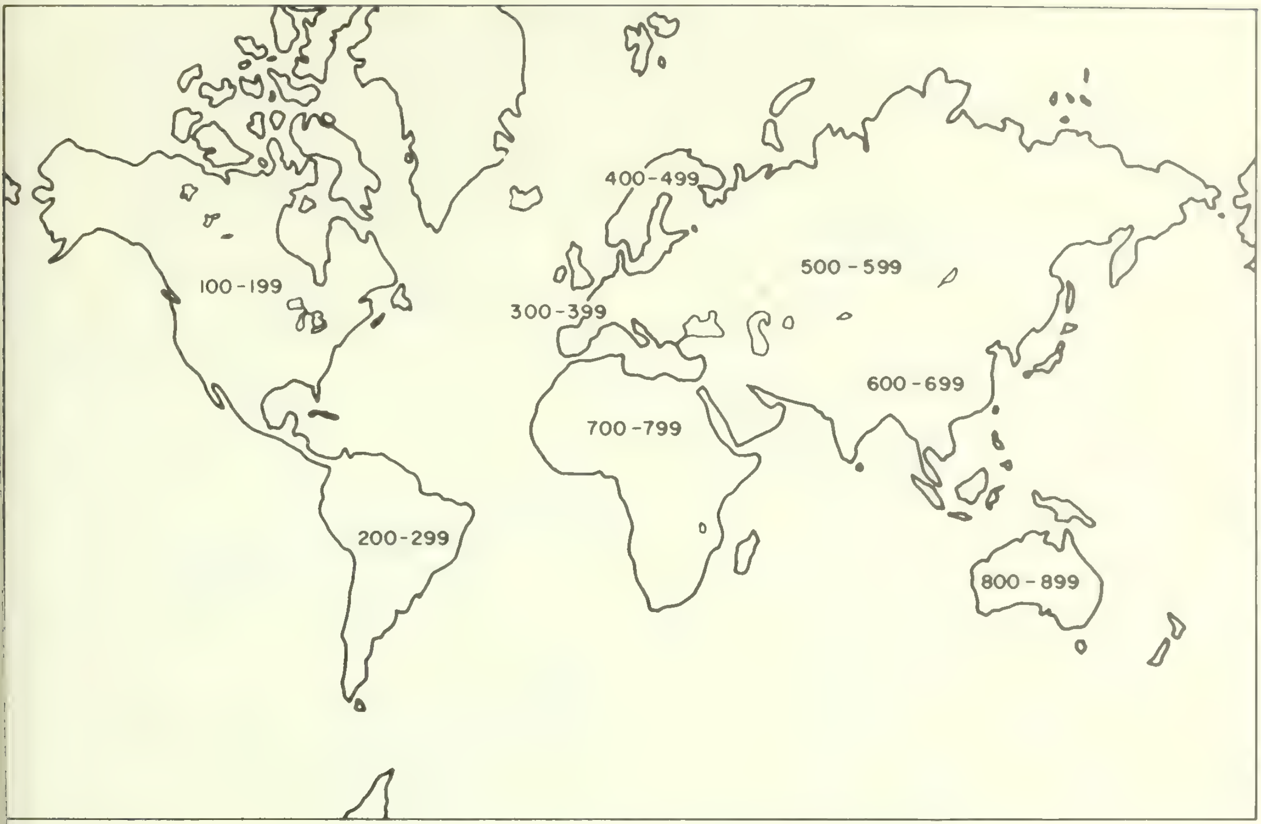
Type	Use	Specifications	Manufacturer	User
X-ray Generators				
Softex	check seeds from controlled crosses (R)	Type I.F.-0310 (K.M.-5M)	Softex Co., Ltd. 6, 7, 1-Chome, Shibuya Shibuya-ku, Tokyo, Japan	151
Softex	seed tests (R)	Model EMB	Softex Co., Ltd. (see above)	600, 701
Softex	seed tests (R)	Model EM	Softex Co., Ltd. (see above)	610
Faxitron	determine maturity, damage soundness (P,L,R)	Model 804	Hewlett-Packard McMinnville Division 500 Linke Street McMinnville, OR 97128 USA	100, 103 152
Faxitron	determine maturity, damage, soundness (P,L,R)	Model 805	Hewlett-Packard (see above)	106, 300, 801
Balteau	determine maturity soundness (L,R)	Baltograph BF 50/20	Balteau B-4610 Beyne-Heusay Belguim	360
G.E.	seed tests	LC-90 industrial machine; 40 kvp at 5 Ma	General Electric Co. 48855 Electric Ave. Milwaukee, WI 53219 USA	154
FKA	seed tests (R)	FKA	O Y Havemann, Ltd. 5-571 00 Nässjö Sweden	452
-ray apparatus	seed tests	--	local	320
ccessory Equipment				
rocessor	develops Kodak paper prints (L,P)	Kodak Industrex Instant Proc. Model P-1	Eastman Kodak Co. Rochester, NY, 14650, USA	106
rint washer	preserves paper prints (L,P)	Richard 18 in. Model	Richard Manufacturing 5914 Noble Ave. Van Nuys, CA 91401 USA	106
ilm holder	holds Polaroid film (P,L,R)	Polaroid 4 x 5 Land Film Holder No. 545	Polaroid Corp. 89 Second Ave. Waltham, MA, 02154, USA	152
lm reader	magnifier for radiograph viewing on screen (L,R)	Merkur 3-S	OCE-Ingut, Ltd. S-57100 Nässjö Sweden	452
diograph reader	radiograph viewing (R)	Wilnosol	Wilhelm Nosbüsch KG Birkenstrasse 71 4 Düsseldorf West Germany (FDR)	450
lio contraster	radiograph viewing (R)	Model HLC-100E 4 x magn; 100 x 100 mm film size (see Kamra, 1974)	N. V. Optische Ind. Delft, Holland	450

Type	Use	Specifications	Manufacturer	User
Accessory Equipment				
Radiograph viewer	radiograph viewing (R)	- -	Picker Industrial 1020 London Rd. Cleveland, OH 44110 USA	100
Treatment frame	treatment with contrast agents (R)	treats and holds 25 seeds (see Simak, 1974)	local	450
Stereo-radioscope	stero-radiograph viewing (R)	(see Vozzo, 1974)	local	100
Template	transfer of seed from film to germination tray	(see Wang, 1974)	local	154

For other information on tree seed radiography, see: Wiersma, 1976.

Specialized and Miscellaneous Equipment

Type	Use	Specifications	Manufacturer	User
Seed pelleter	pellets Eucalyptus seeds (R)	reciprocating-rotating pan (see Millier & Bensin, 1974)	local	105
Automatic pipette	watering germination trays (R)	Exelo Double-Action Pipette	Gallenkamp P. O. Box 290 Technico House, Christopher Str. London E.C. 2, England	701
Freeze-drier	reduces seed moisture via freeze-drying (R,L)	Christ Delta I; 2 kg capacity; local modifications	Firma Martin Christ BRD-3360 Osterode am Harz West Germany (FDR)	360
Vitascope	viability tests (L)	based on tetrazolium staining	A/S Foss Electric 39 Roskiderej Hillerød, Denmark	104
Vacuum oven	viability tests	aid in tetrazolium stain tests; 10 to 110°C.	local	380
Fumigation cabinet	seed fumigation (P,R)	90 x 70 x 50 cm, W/exhaust fan	Centrioflo Pty., Ltd. Conditionaire House 2 A General Holmes Dr. Brighton-le-Sands, N.S.W. Australia	801
Temperature recorder	monitor temp. in germinators (L)	7-day chart, 3 sensors	Otakeiki Seisakusho Co., Ltd. 39-20, 2-Chome Narita-Higashi Suginami-ku Tokyo, Japan	801
Seed soaker	to fully imbibe seeds(L)	metal tray w/screen stand for seed; overhead spray nozzles	local	153
Seed grinder	catalase activity tests (R)	Ultra Turax grinder	Ika-Werk 7813 Stanfen Breisgau, West Germany (FDR)	350
eed herbarium cabinet	store true samples (L)	- -	E. L. Erickson Prod. Brookings, SD 57006, USA	600



USER KEY — CONTRIBUTING LABORATORIES

00-199 North America

100-149 USA

100 - U.S. Forest Service
Southern Forest Experiment Station
Forest Tree Seed Laboratory
P. O. Box 906
Starkville, MS 39759

101 - U.S. Forest Service
Rocky Mountain Forest Experiment Station
Forestry Sciences Laboratory, NAV
Flagstaff, AZ 86001

102 - U.S. Forest Service
Rocky Mountain Forest Experiment Station
Forestry Sciences Laboratory
East Campus, Univ. Nebraska
Lincoln, NB 68503

103 - U.S. Forest Service
North Central Forest Experiment Station
Bedford, IN 47421

104 - International Paper Co.
Southern Kraft Division
Southlands Experiment Forest
Bainbridge, GA 31717

105 - U.S. Forest Service
Southeastern Forest Experiment Station
P. O. Box 938
Lehigh Acres, FL 33936

106 - Pennsylvania Bureau of Forestry
Mont Alto Nursery
Mont Alto, PA 17237

150-199 Canada

150 - Department of Forest Resources
University of New Brunswick
Fredericton, N.B.
E3B 5A3

151 - Forest Tree Seed Laboratory
British Columbia Forest Service
Research Division
Victoria, British Columbia
V8V 1 x 5

152 - Pacific Forest Research Center
Canadian Forestry Service
506 West Burnside Road
Victoria, B.C.
V8Z 1M5

153 - PFRA Tree Nursery
Indian Head, Saskatchewan
SOG 2K0

154 - Petawawa Forest Experiment Station
Canadian Forestry Service
Chalk River, Ontario
K0J 1J0

200-299 Central and South America

300-399 Southern and Western Europe

300-319 Great Britain

300 - Forestry Commission
Forest Research Station, Seed Branch
Alice Holt Lodge
Wrecclesham, Farnham, Surrey

320-339 France

320 - C.N.R.F.
Station d'Amelioration des Arbres Forestiers
Champenoux 54280
Seichamps

321 - C.T.G.R.E.F.
Division "Graines et Plants Forestiers"
Domaine des Barres 45290
Nogent-sur-Bernisson

322 - International Versepuy Tree Seeds Bank
43 — Lepuy

340-349 Belgium

340 - Laboratoire d'Ecologie Végétale
Place Croix du Sud, 4
1348 Louvain-la-Neuve

350-359 West Germany (FDR)

350 - Dr. Werner Schmidt
205 Hamburg 80
Glindersweg 72

360-369 Switzerland

360 - Swiss Forest Research Institute
Dept. Seeds and Plants
CH-8903
Birmensdorf/ZH

361 - Association forestière Vaudoise
"La Pépinière"
CH-1261
Glenolier

362 - Kantonales Forstinspektorat
Gürtelstr. 24
CH-7000
Chur

370-379 Austria

370 - Forstliche Bundesversuchsanstalt
Prüfstelle Für Forstsamen
A-1131, Vienna

380-389 Italy

380 - Laboratorie per i Semi Forestali
Facolta di Agraria
Piazzale Cascine, 18
50144 Firenze

381 - Azienda di Stato
per le Foreste Demaniali
52036 Pieve S. Stefano
Arezzo

390-399 Other

390 - Ministry of Agriculture and Natural Resources
Forest Department
Nicosia, Cyprus

400-499 Northern Europe

400-424 Denmark

400 - Danish State Forestry
Tree Improvement Station
3050 Humlebaek

401 - Hedeselskabets Centralplanteskole
Tvilum Skovgaard
8882 Faarvang

425-449 Norway

425 - Statens Skogfroverk
State Forest Seed Extractory and Testing Sta.
N-2301 Hamar

450-479 Sweden

450 - Institute of Reforestation
Royal College of Forestry
S-104 05 Stockholm 50

452 - Institute for Forest Improvement
Northern Research Station
Fack 3
S-910 3b Sävar

500-599 Eastern Europe

580-589 Hungary

580 - Forest Research Institute
H-9600 Sárvár

581 - Chair of Afforestation
Forestry and Timber Ind. University
9400 Sopron

600-699 South and East Asia

600 - Seed Testing Laboratory
Forest Research Institute and Colleges
P. O. New Forest
Dehradun

610-619 Japan

610 - Government Forest Experiment Station
Ministry of Agriculture and Forestry
Meguro, Tokyo

620-629 Thailand

620 - Thai-Danish Pine Project
P. O. HOD
Chiengmai

700-799 Africa

700 - S. A. Forest Investments, Ltd.
P. O. Box 69, Sabie
Eastern Transvaal, 1260
South Africa

701 - University of Stellenbosch
Faculty of Forestry
Stellenbosch, 7600
South Africa

702 - Forestry Research Institute of Malawi
P. O. Box 270
Zomba, Malawi

703 - Forest Research Centre
Rhodesia Forestry Commission
P. O. Box HG 595
Highlands, Salisbury
Rhodesia

704 - Ministry of Natural Resources and Tourism
Forest Division, Silviculture Research Station
P. O. Box 95
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800-849 Australia

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F. T. BONNER

1977. Equipment and supplies for collecting, processing, storing and testing forest tree seed. USDA For. Serv. Gen. Tech. Rep. SO-13, 35 p. South. For. Exp. Stn., New Orleans, La.

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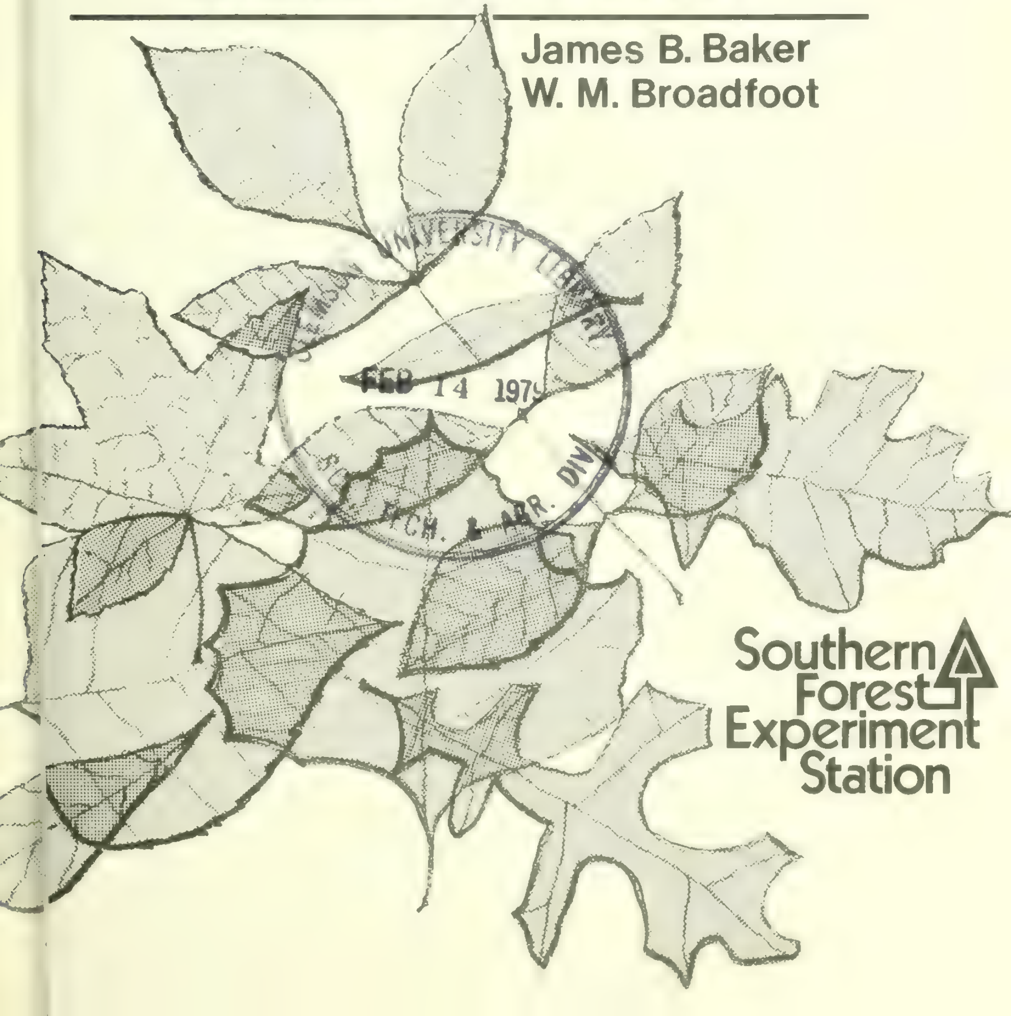
General Technical Report SO-14

A PRACTICAL FIELD METHOD OF
SITE EVALUATION FOR EIGHT IMPORTANT SOUTHERN HARDWOODS

James B. Baker
W. M. Broadfoot



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SUMMARY

This paper presents a new method of site evaluation for cottonwood, sweetgum, sycamore, green ash, and Nuttall, water, willow, and cherrybark oaks. The method incorporates an evaluation of the physical, moisture, nutrient, and aeration properties of a soil into a site quality rating. Field tests have demonstrated the accuracy of the technique. The site evaluation technique also provides a basis for possible soil improvement treatments for the eight hardwood species and estimates of potential productivity for cottonwood plantations.

1977

A Practical Field Method of Site Evaluation For Eight Important Southern Hardwoods

JAMES B. BAKER
AND
W. M. BROADFOOT

This report is a field guide to be used in estimating the suitability of sites for eight important hardwood species. In establishing hardwood plantations, the forest manager must know whether a site is suitable for a particular species, and for investment planning he should have some idea of the potential productivity of the site.

Tables 1-7 are the guides for applying the site-evaluation method; instructions on their use are given beginning on page 2. For cottonwood, a table (table 8) that gives expected ranges in tree growth and volume production is presented. A glossary of terms that may be unfamiliar to many readers is included as an appendix.

BACKGROUND

Many acres of hardwood plantations are established each year throughout the eastern United States. Johnson and Kerr (1976) reported that by 1981 cottonwood plantations could total about 70,000 acres, a 30,000-acre increase in 5 years. Other species, such as sycamore, sweetgum, and green ash, are also being planted at accelerated rates throughout the South.

The techniques now available to aid in site selection and evaluation for hardwoods involve either objective or subjective approaches which have inherent shortcomings that limit their usefulness. The problems of objectively selecting and quantifying measurable soil variables that consistently reflect the growth potential of hardwoods over wide geographic areas appear to be insurmountable (Broadfoot 1969). On the other hand, subjective approaches provide only broad classes of soil suitability or productivity for hardwoods (Broadfoot 1964, Broadfoot et al. 1972, Maisenhelder 1960, McKnight 1970, and Smith 1957).

James B. Baker is Principal Soil Scientist and W. M. Broadfoot, now retired, was Principal Soil Scientist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station, Forest Service USDA, in cooperation with the Mississippi Agricultural and Forestry Experiment Station and the Southern Hardwood Forest Research Group.

We propose a new technique of site evaluation that combines the best features of objective and subjective approaches. The technique is based on our experience and is not the result of formal experimentation but should provide foresters with an accurate way of evaluating a site's suitability for any of eight hardwood species. The method can also be used to obtain estimates of potential volume production of cottonwood at various ages.

The advantages of the technique are: (1) it provides accurate estimates of site index under any soil or site condition; (2) it can be applied throughout the southern hardwood region except in those mountainous areas where aspect is important; (3) it does not require identification of soil series; and (4) it provides guidelines for soil ameliorative treatments. In the future, the method could possibly be modified to include species of trees from throughout the world if allowance is made for differences in climate, soils, and topography.

With field-plot data for hardwoods (Broadfoot 1976), the technique was field tested for each species for a variety of soils and physiographic areas. Site index values estimated for a particular site by the new method were compared to measured site index values obtained by Broadfoot. These comparisons were subjected to correlation analysis and to the chi-square test of accuracy (Freese 1960). On the average, 20 sites were tested for each species; correlation coefficients ranged from 0.93 for sweetgum to 0.99 for cottonwood. The chi-square test of accuracy indicated that the new evaluation technique should provide estimates of site index that are within 5 feet of measured site index values 99 percent of the time.

BASIS FOR AND DEVELOPMENT OF THE TECHNIQUE

Growth of hardwoods is dependent primarily on four major soil factors (Broadfoot 1969, Broadfoot et al. 1972, Kaszkurewicz 1973, Schreiner 1959, Waring 1961). These factors are:

(1) Soil physical condition.
(2) Moisture availability during the growing season.
(3) Nutrient availability.
(4) Aeration.

Each major factor consists of many soil and site properties that affect tree growth. The interaction of these properties within and among the major soil factors makes evaluation of a site a complex task.

The basis of our approach is the assumption that each of the major factors is responsible for a certain percentage of tree growth. The proportion of growth accounted for by each major factor is composed of the contributions made by each of its soil-site properties.

Tables 1-7 list the major soil factors and soil-site properties for the eight species. The tables also present a range of soil-site conditions, from best to poor, that are likely to occur for each soil property. The soil-site conditions for each property are assigned numerical site-quality ratings

(SQR), which are given in brackets. The SQR values were first estimated for the best site conditions (see fig. 1) and were then assigned to medium and poor sites by estimating height reductions caused by less than optimal conditions.

FIELD USE OF THE EVALUATION TECHNIQUE

To obtain an SQR value for a particular species, match the soil-site conditions of your area as closely as possible to the range of conditions listed for each soil-site property in the appropriate table. A 30-year site index for cottonwood or a 50-year site index for the other species is obtained by adding the SQR's for each soil-site property. If a total SQR for any site does not exceed 80 feet for cottonwood, 75 feet for sweetgum and Nuttall oak, 70 feet for sycamore and water, willow, and cherrybark oaks, and 65 feet for green ash the area should be considered unsuitable for that species unless soil amelioration is used to alleviate adverse soil-site conditions.

If an exact match is not possible, interpolate between conditions listed in the tables. If you are unable to determine a specific soil-site condition, do not hesitate to make an educated guess; a few poor estimations probably will not cause serious errors in the final site quality rating. A few hours of instruction from a soil scientist should enable people who are unfamiliar with various soil-site conditions to make accurate estimates.

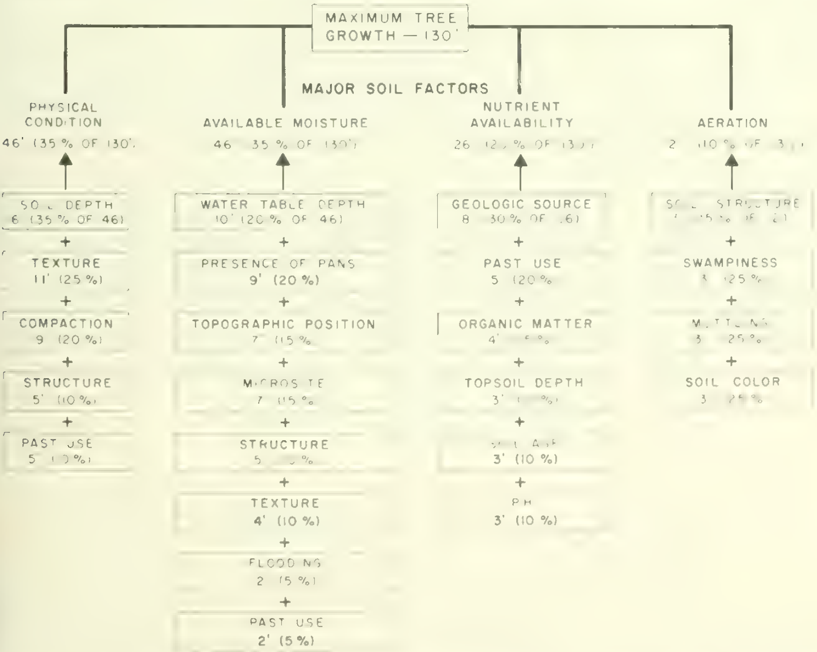

Figure 1.—*Contribution of various soil-site properties to the four major soil factors and to cottonwood growth (maximum growth expected on an ideal site at age 30).*

As an example of how the technique is applied, let us assume that the location to be evaluated is a recently abandoned old field in the Mississippi River floodplain that had been under intensive agronomic cropping for 25 years. The area is level and not subject to flooding. The soil is a loam with no profile development; it is granular in structure but is moderately compacted and has a plowpan at 10 inches. It is brown and mottled at 36 inches. A water table occurs at 5 feet during the growing season, pH is 6.5, and there is less than 1 percent organic matter in the A-horizon.

The SQR's for each soil-site characteristic of the hypothetical area, taken from table 1, are summed and produce the following site evaluation for cottonwood:

MAJOR SOIL FACTORS

(1) Physical condition		(2) Moisture availability		(3) Nutrient availability		(4) Aeration	
		Water table ..	10	Geologic source	8		
		Pans	6				
		Position	7	Past use	-3		
Soil depth and pans ..	11	Microsite	5				
Texture	11	Structure	5	% organic matter	-3	Structure	3
Compaction ..	6	Texture	4	Topsoil	3	Swampiness ..	3
Structure	5	Flooding	-1	Soil age	3	Mottling	3
Past use	-2	Past use	-1	pH	3	Color	3
Total	31 ft		35 ft		11 ft		12 ft
(Total possible)	(46 ft)		(46 ft)		(26 ft)		(12 ft)

TOTAL SQR OR SITE INDEX = 89 ft

This evaluation indicates that the site index for cottonwood on this particular area is 89 feet at 30 years.

By comparing the values obtained for each major factor with the maximum values possible for an ideal site, we can determine which major factor limits growth. In the example, physical condition received 31 of the 46 (67 percent) points possible; moisture availability and aeration received 76 and 100 percent, respectively, of the total possible points. Nutrient availability, however, received only 42 percent of its total possible points. Thus, a lack of sufficient nutrients would probably limit growth on this site, and fertilization might be used to improve the growth of cottonwood.

ESTIMATES OF COTTONWOOD VOLUME AND DRY MATTER PRODUCTION BY SITE CLASSES

Once a forest manager has calculated the SQR for cottonwood for an area, he can obtain from table 8 an estimate of cottonwood productivity for various stages of development. These production estimates were obtained from measured yields in cottonwood plantations through age 15 and from natural stand data for ages 20 through 30 years. At present, plantation data are not adequate to prepare productivity tables for the other species. Derivation of the estimates for cottonwood was based on the following assumptions:

(1) Site preparation and plantation culture through the first growing season as described by McKnight (1970).

(2) Planting density of approximately 430 trees per acre; 20% planting mortality and 1% natural mortality per year after establishment.

(3) Proper thinning to maintain adequate growing space for crop trees. These thinnings included:

  a. One-half of the trees (1/2 of the basal area) removed per acre as row thinnings on the Class I and II sites at age 5.

  b. One-half of the trees (1/2 of the BA) removed as row thinnings on the Class III sites and one-third of the BA (38% of the trees from the lower half of the diameter range) removed by selection on the Class I and II sites at age 10.

  c. One-third of the BA (38% of the trees from the lower half of the diameter range) removed by selection on all site classes at age 15.

  d. One-third of the BA (38% of the trees from the lower half of the diameter range) removed by selection on the Class I sites at age 20.

Production estimates presented at each age are for standing trees at that time and do not include previous thinnings, but net production (final harvest cut + previous thinnings) is given for age 30. Net production for ages other than 30 years can be calculated by summing the volume of standing trees at the intermediate age and the volume obtained from previous thinnings. For example, net production in cords for the Class I sites at age 15 is 50 + (1/3 of 46) or 15.3 + (1/2 of 17) or 8.5, giving a total of 73.8 cords per acre (Table 8).

It should be noted that values for cu. ft., cords, M bd. ft., and dry matter represent the total production for a single product. For example, at age 30 the Class I sites would produce 11,170 cu. ft. or 124 cords or 39 and 49 M bd. ft. (Doyle and Int.) or 130 tons of stem per acre (Table 8). Estimates are not provided for multiple products.

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Table 1. — *Soil-site properties influencing the four major soil factors and thus cottonwood growth*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 1. Physical condition		
Soil depth and presence of artificial or inherent pan	Deep soil (> 4 feet); without pan [16][1]	Medium depth (2-4 feet), or a soil with a plowpan [11]	Shallow soil (< 2 feet), or a soil with an inherent pan [-11]
Texture (in rooting zone)	Medium-textured; silty or loamy [11]	Coarse-textured; sandy [8]	Fine-textured; clayey [-4]
Compaction (in surface foot)	No compaction; loose, porous, friable, bulk density < 1.4 g/cc [9]	Moderately compacted; firm, moderately tight, bulk density 1.4-1.7 g/cc [6]	Strongly compacted; tight, bulk density > 1.7 g/cc [-3]
Structure (in rooting zone)	Granular; single-grained; massive (if sandy, loamy, or silty) [5]	Prismatic; blocky [3]	Massive (if clayey); platy [-3]
Past use and present cover	Undisturbed; near-virgin forest cover [5]	Moderate cultivation; cultivated < 20 years, or open with grass [2]	Intensive cultivation; cultivated > 20 years, or open and bare [-2]

Continued

Table 1. — *Soil-site properties influencing the four major soil factors and thus cottonwood growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
Factor 2. Moisture availability during growing season			
Water table depth	2-6′ [10]	1-2′; 7-10′ [7]	< 1′ [unsuitable]; > 10′ [0][2]
Artificial or inherent pans	No pans [9]	Plowpan [6]	Inherent pan [-6]
Topographic position	Floodplain or stream bottom [7]	Stream terraces or lower slopes [5]	Upland [-5]
Microsite	Concave; depression, pocket, trough [7]	Level; flat [5]	Convex; ridge, mound [-2]
Structure (in rooting zone)	Granular; massive (if silty, loamy, or clayey); stratified [5]	Prismatic; blocky [3]	Massive (if sandy); platy; single-grained [-3]
Texture (in rooting zone)	Silty or loamy (or stratified) [4]	Clayey [2]	Sandy [-2]
Flooding	Winter through spring [2]	Winter only [1]	None [-1]; continuous [unsuitable]
Past use and present cover	Undisturbed; near-virgin forest cover [2]	Moderate cultivation; cultivated < 10 years [1]	Intensive cultivation; cultivated > 10 years [-1]

Continued

Table 1. — *Soil-site properties influencing the four major soil factors and thus cottonwood growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
Factor 3. Nutrient availability			
Geologic source	Mississippi River, Loess, Blackland [8]	Mixed Coastal Plain and other [5]	Coastal Plain [-5]
Past use and present cover	Undisturbed; near-virgin, forest cover, cultivated < 5 years [5]	Moderate cultivation; cultivated 5-10 years, or open with grass [3][3]	Intensive cultivation; cultivated > 10 years, or open and bare [-3][3]
Organic matter (A-horizon)	> 2% [4]	1-2% [3]	< 1% [-3]
Depth of topsoil (A-horizon)	> 6″ or no profile development [3]	3-6″ [2]	< 3″ [-2]
Soil age	Young, no profile development (Entisols) [3]	Medium, moderate profile development (Inceptisols) [2]	Old, well-developed profile, leached (Alfisols) [-2]
pH (in rooting zone	5.5-7.5 [3]	4.5-5.5 or 7.6-8.5 [2]	< 4.5 or > 8.5 [-2]
Factor 4. Aeration			
Soil structure (in rooting zone)	Granular, porous; single-grained; or massive (if sandy, loamy, or silty) [3]	Prismatic; blocky [2]	Massive (if clayey); platy [-2]
Swampiness	Wet in winter only [3]	Wet January-July [2]	Waterlogged all year [Unsuitable]
Mottling	None to 18″ depth [3]	None to 8″ depth [2]	Mottled to surface [-2]
Soil color (A-horizon)	Black, brown, red [3]	Yellow, brownish-gray [2]	Gray [-2]

[1] Each bracketed number indicates the site quality rating (SQR) of a particular soil-site condition.

[2] If the soil is a sand or loamy sand, then [-20].

[3] If cultural practices included annual fertilization, then [4].

Table 2. — *Soil-site properties influencing the four major soil factors and thus sweetgum growth*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
Factor 1. Physical condition			
Soil depth and presence of artificial or inherent pan	Deep soil ($>$ 4 feet); without pan [6][1]	Medium depth (2-4 feet), or a soil with a plowpan [4]	Shallow soil ($<$ 2 feet), or a soil with an inherent pan [-2]
Texture (in rooting zone)	Medium-textured; silty or loamy [4]	Coarse-textured; sandy [2]	Fine-textured; clayey [1]
Compaction (in surface foot)	No compaction; loose, porous, friable, bulk density $<$ 1.4 g/cc [6]	Moderately compacted; firm, moderately tight, bulk density 1.4-1.7 g/cc [4]	Strongly compacted; tight, bulk density $>$ 1.7 g/cc [-2]
Structure (in rooting zone)	Granular; blocky single-grained; massive (if sandy, loamy, or silty) [6]	Prismatic; platy [4]	Massive (if clayey) [0]
Past use and present cover	Undisturbed; near-virgin forest cover [8]	Moderate cultivation; cultivated $<$ 20 years, or open with grass [5]	Intensive cultivation; cultivated $>$ 20 years, or open and bare [2]

Continued

Table 2. — *Soil-site properties influencing the four major soil factors and thus sweetgum growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 2. Moisture availability during growing season		
Water table depth	2-6′ [6]	1-2′; 7-10′ [3]	<1′[unsuitable]; >10′ [-3]²
Artificial or inherent pans	No pans [6]	Plowpan [3]	Inherent pan [-3]
Topographic position	Floodplain or stream bottom [5]	Stream terraces or lower slopes [3]	Upland [-2]
Microsite	Concave; depression, pocket, trough [2]	Level; flat [1]	Convex; ridge, mound [-2]
Structure (in rooting zone)	Granular; blocky; massive (if silty, loamy, or clayey); stratified [5]	Prismatic; platy [3]	Massive (if sandy); single-grained [-1]
Texture (in rooting zone)	Silty or loamy, (or stratified) [5]	Clayey [2]	Sandy [0]
Flooding	Winter through spring [5]	Winter only [3]	None [0]; Continuous [Unsuitable]
Past use and present cover	Undisturbed; near-virgin, forest cover [2]	Moderate cultivation; cultivated < 10 years [1]	Intensive cultivation; cultivated > 10 years [0]

Continued

Table 2. — *Soil-site properties influencing the four major soil factors and thus sweetgum growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
Factor 3. Nutrient availability			
Geologic source	Mississippi River, Loess, Blackland [5]	Mixed Coastal Plain and other [4]	Coastal Plain [2]
Past use and present cover	Undisturbed; near-virgin, forest cover, cultivated < 5 years [5]	Moderate cultivation; cultivated 5-10 years, or open with grass [3][3]	Intensive cultivation; cultivated > 10 years, or open and bare [1][3]
Organic matter (A-horizon)	> 2% [4]	1-2% [2]	< 1% [-2]
Depth of topsoil (A-horizon)	> 6″ or no profile development [5]	3-6″ [2]	< 3″ [-3]
Soil age	Young, no profile development (Entisols) [4]	Medium, moderate profile development (Inceptisols) [2]	Old, well-developed profile, leached (Alfisols) [0]
pH (in rooting zone)	5.5-7.5 [1]	4.5-5.5 or 7.6-8.5 [0]	< 4.5 or > 8.5 [-1]
Factor 4. Aeration			
Soil structure (in rooting zone)	Granular, porous; single-grained; or massive (if sandy, loamy, or silty); blocky [8]	Prismatic; platy [4]	Massive (if clayey) [-2]
Swampiness	Wet in winter only [8]	Wet January-July [4]	Waterlogged all year [Unsuitable]
Mottling	None to 18″ depth [7]	None to 8″ depth [5]	Mottled to surface [-2]
Soil color (A-horizon)	Black, brown, red [7]	Yellow, brownish-gray [4]	Gray [-2]

[1] Each bracketed number indicates the site quality rating (SQR) of a particular soil-site condition.

[2] If the soil is a sand or loamy sand, then [-10].

[3] If cultural practices included annual fertilization, then [4].

Table 3. — *Soil-site properties influencing the four major soil factors and thus sycamore growth*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 1. Physical condition		
Soil depth and presence of artificial or inherent pan	Deep soil ($>$ 4 feet); without pan [10][1]	Medium depth (2-4 feet), or a soil with a plowpan [5]	Shallow soil ($<$ 2 feet), or a soil with an inherent pan [-5]
Texture (in rooting zone)	Medium-textured; silty or loamy [8]	Coarse-textured; sandy [4]	Fine-textured; clayey [0]
Compaction (in surface foot)	No compaction; loose, porous, friable, bulk density $<$ 1.4 g/cc [8]	Moderately compacted; firm, moderately tight, bulk density 1.4-1.7 g/cc [4]	Strongly compacted; tight, bulk density $>$ 1.7 g/cc [-2]
Structure (in rooting zone)	Granular; single-grained; massive (if sandy, loamy, or silty) [3]	Prismatic; blocky [1]	Massive (if clayey); platy [-3]
Past use and present cover	Undisturbed; near-virgin forest cover [3]	Moderate cultivation; cultivated $<$ 20 years, or open with grass [1]	Intensive cultivation; cultivated $>$ 20 years, or open and bare [0]

Continued

Table 3. — *Soil-site properties influencing the four major soil factors and thus sycamore growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 2. Moisture availability during growing season		
Water table depth	2-6′ [5]	1-2′; 7-10′ [2]	< 1′ [unsuitable]; > 10′ [-5][2]
Artificial or inherent pans	No pans [5]	Plowpan [2]	Inherent pan [-5]
Topographic position	Floodplain or stream bottom [2]	Stream terraces or lower slopes [1]	Upland [-2]
Microsite	Concave; depression, pocket, trough [2]	Level; flat [1]	Convex; ridge, mound [-2]
Structure (in rooting zone)	Granular; massive (if silty, loamy, or clayey); stratified [1]	Prismatic; blocky [0]	Massive (if sandy); platy; single-grained [-1]
Texture (in rooting zone)	Silty or loamy, (or stratified) [1]	Clayey [0]	Sandy [-1]
Flooding	Winter through spring [3]	Winter only [1]	None [-5]; continuous [unsuitable]
Past use and present cover	Undisturbed; near-virgin, forest cover [1]	Moderate cultivation; cultivated < 10 years [0]	Intensive cultivation; cultivated > 10 years [-1]

Continued

Table 3. — *Soil-site properties influencing the four major soil factors and thus sycamore growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 3. Nutrient availability		
Geologic source	Mississippi River Loess, Blackland [12]	Mixed Coastal Plain and other [8]	Coastal Plain [3]
Past use and present cover	Undisturbed; near-virgin, forest cover, cultivated < 5 years [10]	Moderate cultivation; cultivated 5-10 years, or open with grass [6][3]	Intensive cultivation; cultivated > 10 years, or open and bare [2][3]
Organic matter (A-horizon)	> 2% [6]	1-2% [3]	< 1% [0]
Depth of topsoil (A-horizon)	> 6″ or no profile development [6]	3-6″ [2]	< 3″ [-4]
Soil age	Young, no profile development (Entisols) [4]	Medium, moderate profile development (Inceptisols) [2]	Old, well-developed profile, leached (Alfisols) [-1]
pH (in rooting zone)	5.5-7.5 [1]	4.5-5.5 or 7.6-8.5 [0]	< 4.5 or > 8.5 [-1]
	Factor 4. Aeration		
Soil structure (in rooting zone)	Granular, porous; single-grained; or massive (if sandy, loamy, or silty) [7]	Prismatic; blocky [4]	Massive (if clayey); platy [-4]
Swampiness	Wet in winter only [10]	Wet January-July [8]	Waterlogged all year [Unsuitable]
Mottling	None to 18″ depth [12]	None to 8″ depth [10]	Mottled to surface [-5]
Soil color (A-horizon)	Black, brown, red [10]	Yellow, brownish-gray [8]	Gray [-5]

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[1] Each bracketed number indicates the site quality rating (SQR) of a particular soil-site condition.

[2] If the soil is a sand or loamy sand, then [-10].

[3] If cultural practices included annual fertilization, then [8].

Table 4. — *Soil-site properties influencing the four major soil factors and thus green ash growth*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 1. Physical condition		
Soil depth and presence of artificial or inherent pan	Deep soil (> 4 feet); without pan [8][1]	Medium depth (2-4 feet), or a soil with a plowpan [5]	Shallow soil (< 2 feet), or a soil with an inherent pan [-3]
Texture (in rooting zone)	Medium-textured; silty or loamy [2]	Coarse-textured; sandy [1]	Fine-textured; clayey [-1]
Compaction (in surface foot)	No compaction; loose, porous, friable, bulk density < 1.4 g/cc [5]	Moderately compacted; firm, moderately tight, bulk density 1.4-1.7 g/cc [3]	Strongly compacted; tight, bulk density > 1.7 g/cc [0]
Structure (in rooting zone)	Granular; single-grained; massive (if sandy, loamy, or silty) [2]	Prismatic; blocky [1]	Massive (if clayey); platy [0]
Past use and present cover	Undisturbed; near-virgin forest cover [4]	Moderate cultivation; cultivated < 20 years, or open with grass [2]	Intensive cultivation; cultivated > 20 years, or open and bare [1]

Continued

Table 4. — *Soil-site properties influencing the four major soil factors and thus green ash growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 2. Moisture availability during growing season		
Water table depth	2-6′ [10]	1-2′ [7]; 7-10′ [5]	< 1′[0]; > 10′ [-5][2]
Artificial or inherent pans	No pans [9]	Plowpan [5]	Inherent pan [-2]
Topographic position	Floodplain or stream bottom [10]	Stream terraces or lower slopes [7]	Upland [0]
Microsite	Concave; depression, pocket, trough [5]	Level; flat [3]	Convex; ridge, mound [0]
Structure (in rooting zone)	Granular; massive (if silty, loamy, or clayey); stratified [2]	Prismatic; blocky [1]	Massive (if sandy); platy; single-grained [-1]
Texture (in rooting zone)	Silty or loamy, (or stratified) [2]	Clayey [1]	Sandy [-1]
Flooding	Winter through spring [7]	Winter only [4]	None [-3]; continuous [unsuitable]
Past use and present cover	Undisturbed; near-virgin forest cover [2]	Moderate cultivation; cultivated < 10 years [1]	Intensive cultivation; cultivated > 10 years [0]

Continued

Table 4. — *Soil-site properties influencing the four major soil factors and thus green ash growth (continued)*

Soil-site property	Soil-site condition and relative quality Best	 Medium	 Poor
	Factor 3. Nutrient availability		
Geologic source	Mississippi River, Loess, Blackland [6]	Mixed Coastal Plain and other [2]	Coastal Plain [-2]
Past use and present cover	Undisturbed; near-virgin forest cover, cultivated < 5 years [6]	Moderate cultivation; cultivated 5-10 years, or open with grass [3][3]	Intensive cultivation; cultivated > 10 years, or open and bare [-1][3]
Organic matter (A-horizon)	> 2% [4]	1-2% [2]	< 1% [-1]
Depth of topsoil (A-horizon)	> 6″ or no profile development [4]	3-6″ [2]	< 3″ [-1]
Soil age	Young, no profile development (Entisols) [3]	Medium, moderate profile development (Inceptisols) [2]	Old, well-developed profile, leached (Alfisols) [0]
pH (in rooting zone)	5.5-7.5 [3]	4.5-5.5 or 7.6-8.5 [2]	< 4.5 or > 8.5 [-2]
	Factor 4. Aeration		
Soil structure (in rooting zone)	Granular, porous; single-grained; or massive (if sandy, loamy, or silty) [3]	Prismatic; blocky [2]	Massive (if clayey); platy [0]
Swampiness	Wet in winter only [3]	Wet January-July [2]	Waterlogged all year [0]
Mottling	None to 18″ depth [2]	None to 8″ depth [1]	Mottled to surface [0]
Soil color (A-horizon)	Black, brown, red [2]	Yellow, brownish-gray [1]	Gray [0]

[1] Each bracketed number indicates the site quality rating (SQR) of a particular soil-site condition.

[2] If the soil is a sand or loamy sand, then [-10].

[3] If cultural practices included annual fertilization, then [4].

Table 5.—*Soil-site properties influencing the four major soil factors and thus Nuttall oak growth*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 1. Physical condition		
Soil depth and presence of artificial or inherent pan	Deep soil (> 4 feet); without pan [8][1]	Medium depth (2-4 feet), or a soil with a plowpan [5]	Shallow soil (< 2 feet), or a soil with an inherent pan [-3]
Texture (in rooting zone)	Medium-textured; silty or loamy [2]	Coarse-textured; sandy [1]	Fine-textured; clayey [-1]
Compaction (in surface foot)	No compaction; loose, porous, friable, bulk density < 1.4 g/cc [6]	Moderately compacted; firm, moderately tight, bulk density 1.4-1.7 g/cc [3]	Strongly compacted; tight, bulk density > 1.7 g/cc [0]
Structure (in rooting zone)	Granular; single-grained; massive (if sandy, loamy, or silty) [3]	Prismatic; blocky [2]	Massive (if clayey); platy [0]
Past use and present cover	Undisturbed; near-virgin forest cover [5]	Moderate cultivation; cultivated < 20 years, or open with grass [3]	Intensive cultivation; cultivated > 20 years, or open and bare [1]

Continued

Table 5.—*Soil-site properties influencing the four major soil factors and thus Nuttall oak growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 2. Moisture availability during growing season		
Water table depth	2-6′ [9]	1-2′; 7-10′ [6]	< 1′ [unsuitable]; > 10′ [0][2]
Artificial or inherent pans	No pans [9]	Plowpan [4]	Inherent pan [-2]
Topographic position	Floodplain or stream bottom [8]	Stream terraces or lower slopes [5]	Upland [0]
Microsite	Concave; depression, pocket, trough [4]	Level; flat [2]	Convex; ridge, mound [0]
Structure (in rooting zone)	Granular; massive (if silty, loamy, or clayey); stratified [2]	Prismatic; blocky [1]	Massive (if sandy); platy; single-grained [0]
Texture (in rooting zone)	Silty or loamy, (or stratified) [2]	Clayey [1]	Sandy [0]
Flooding	Winter through spring [6]	Winter only [3]	None [0]; continuous [unsuitable]
Past use and present cover	Undisturbed; near-virgin, forest cover [2]	Moderate cultivation; cultivated < 10 years [1]	Intensive cultivation; cultivated > 10 years [0]

Continued

Table 5.—*Soil-site properties influencing the four major soil factors and thus Nuttall oak growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
Factor 3. Nutrient availability			
Geologic source	Mississippi River, Loess, Blackland [3]	Mixed Coastal Plain and other [1]	Coastal Plain [-1]
Past use and present cover	Undisturbed; near-virgin forest cover, cultivated < 5 years [6]	Moderate cultivation; cultivated 5-10 years, or open with grass [3][3]	Intensive cultivation; cultivated > 10 years, or open and bare [0][3]
Organic matter (A-horizon)	> 2% [6]	1-2% [3]	< 1% [0]
Depth of topsoil (A-horizon)	> 6″ or no profile development [6]	3-6″ [3]	< 3″ [-3]
Soil age	Young, no profile development (Entisols) [3]	Medium, moderate profile development (Inceptisols) [1]	Old, well-developed profile, leached (Alfisols) [-1]
pH (in rooting zone)	4.5-5.5 [6]	5.6-7.5; < 4.5 [4]	> 7.5 [Unsuitable]
Factor 4. Aeration			
Soil structure (in rooting zone)	Granular, porous; single-grained; or massive (if sandy, loamy, or silty) [7]	Prismatic; blocky [5]	Massive (if clayey); platy [0]
Swampiness	Wet in winter only [7]	Wet January-July [5]	Waterlogged all year [Unsuitable]
Mottling	None to 18″ depth [5]	None to 8″ depth [3]	Mottled to surface [1]
Soil color (A-horizon)	Black, brown, red [5]	Yellow, brownish-gray [2]	Gray [0]

[1] Each bracketed number indicates the site quality rating (SQR) of a particular soil-site condition.

[2] If the soil is a sand or loamy sand, then [-10].

[3] If cultural practices included annual fertilization, then [4].

Table 6. — *Soil-site properties influencing the four major soil factors and thus water oak & willow oak growth*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 1. Physical condition		
Soil depth and presence of artificial or inherent pan	Deep soil (> 4 feet); without pan [6][1]	Medium depth (2-4 feet), or a soil with a plowpan [4]	Shallow soil (< 2 feet), or a soil with an inherent pan [-2]
Texture (in rooting zone)	Medium-textured; silty or loamy [4]	Coarse-textured; sandy [2]	Fine-textured; clayey [1]
Compaction (in surface foot)	No compaction; loose, porous, friable, bulk density < 1.4 g/cc [6]	Moderately compacted; firm, moderately tight, bulk density 1.4-1.7 g/cc [4]	Strongly compacted; tight, bulk density > 1.7 g/cc [-2]
Structure (in rooting zone)	Granular; single-grained; massive (if sandy, loamy, or silty) [6]	Prismatic; blocky [4]	Massive (if clayey); platy [0]
Past use and present cover	Undisturbed; near-virgin forest cover [7]	Moderate cultivation; cultivated < 20 years, or open with grass [4]	Intensive cultivation; cultivated > 20 years, or open and bare [1]

Continued

Table 6. — *Soil-site properties influencing the four major soil factors and thus water oak & willow oak growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 2. Moisture availability during growing season		
Water table depth	2-6′ [5]	1-2′; 7-10′ [2]	< 1′ [unsuitable]; > 10′ [-3][2]
Artificial or inherent pans	No pans [5]	Plowpan [2]	Inherent pan [-2]
Topographic position	Floodplain or stream bottom [5]	Stream terraces or lower slopes [3]	Upland [0]
Microsite	Concave; depression, pocket, trough [2]	Level; flat [1]	Convex; ridge, mound [-3]
Structure (in rooting zone)	Granular; massive (if silty, loamy, or clayey); stratified [5]	Prismatic; blocky [3]	Massive (if sandy); platy; single-grained [-1]
Texture (in rooting zone)	Silty or loamy, (or stratified) [5]	Clayey [3]	Sandy [0]
Flooding	Winter through spring [5]	Winter only [3]	None [−1]; continuous [unsuitable]
Past use and present cover	Undisturbed; near-virgin, forest cover [2]	Moderate cultivation; cultivated < 10 years [1]	Intensive cultivation; cultivated > 10 years [0]

Continued

Table 6. — *Soil-site properties influencing the four major soil factors and thus water oak & willow oak growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
Factor 3. Nutrient availability			
Geologic source	Mississippi River, Loess, Blackland [2]	Mixed Coastal Plain and other [1]	Coastal Plain [0]
Past use and present cover	Undisturbed; near-virgin, forest cover, cultivated < 5 years [5]	Moderate cultivation; cultivated 5-10 years, or open with grass [3][3]	Intensive cultivation; cultivated > 10 years, or open and bare [1][3]
Organic matter (A-horizon)	> 2% [4]	1-2% [2]	< 1% [0]
Depth of topsoil (A-horizon)	> 6″ or no profile development [5]	3-6″ [2]	< 3″ [-3]
Soil age	Young, no profile development (Entisols) [2]	Medium, moderate profile development (Inceptisols) [1]	Old, well-developed profile, leached (Alfisols) [0]
pH (in rooting zone)	4.5-5.5 [5]	5.6-7.5; < 4.5 [3]	> 7.5 [Unsuitable]
Factor 4. Aeration			
Soil structure (in rooting zone)	Granular, porous; single-grained; or massive (if sandy, loamy, or silty) [7]	Prismatic; blocky [5]	Massive (if clayey); platy [0]
Swampiness	Wet in winter only [8]	Wet January-July [4]	Waterlogged all year [Unsuitable]
Mottling	None to 18″ depth [7]	None to 8″ depth [5]	Mottled to surface [-2]
Soil color (A-horizon)	Black, brown, red [7]	Yellow, brownish-gray [5]	Gray [-2]

[1] Each bracketed number indicates the site quality rating (SQR) of a particular soil-site condition.

[2] If the soil is a sand or loamy sand, then [-10].

[3] If cultural practices included annual fertilization, then [4].

Table 7. — *Soil-site properties influencing the four major soil factors and thus cherrybark oak growth*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 1. Physical condition		
Soil depth and presence of artificial or inherent pan	Deep soil ($>$ 4 feet); without pan [6][1]	Medium depth (2-4 feet), or a soil with a plowpan [4]	Shallow soil ($<$ 2 feet), or a soil with an inherent pan [-2]
Texture (in rooting zone)	Medium-textured; silty or loamy [5]	Coarse-textured; sandy [3]	Fine-textured; clayey [1]
Compaction (in surface foot)	No compaction; loose, porous, friable, bulk density $<$ 1.4 g/cc [6]	Moderately compacted; firm, moderately tight, bulk density 1.4-1.7 g/cc [4]	Strongly compacted; tight, bulk density $>$ 1.7 g/cc [-2]
Structure (in rooting zone)	Granular; single-grained; massive (if sandy, loamy, or silty) [6]	Prismatic; blocky [4]	Massive (if clayey); platy [0]
Past use and present cover	Undisturbed; near-virgin forest cover [8]	Moderate cultivation; cultivated $<$ 20 years, or open with grass [4]	Intensive cultivation; cultivated $>$ 20 years, or open and bare [1]

Continued

Table 7. — *Soil-site properties influencing the four major soil factors and thus cherrybark oak growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 2. Moisture availability during growing season		
Water table depth	2-6′ [6]	1-2′; 7-10′ [3]	< 1′ [unsuitable]; > 10′ [-3][2]
Artificial or inherent pans	No pans [6]	Plowpan [3]	Inherent pan [-2]
Topographic position	Floodplain or stream bottom [6]	Stream terraces or lower slopes [4]	Upland [0]
Microsite	Concave; depression, pocket, trough [2]	Level; flat [1]	Convex; ridge, mound [0]
Structure (in rooting zone)	Granular; massive (if silty, loamy, or clayey); stratified [5]	Prismatic; blocky [3]	Massive (if sandy); platy; single-grained [-1]
Texture (in rooting zone)	Silty or loamy, (or stratified) [5]	Clayey [3]	Sandy [0]
Flooding	Winter through spring [6]	Winter only [3]	None [0]; continuous [unsuitable]
Past use and present cover	Undisturbed; near-virgin, forest cover [2]	Moderate cultivation; cultivated < 10 years [1]	Intensive cultivation; cultivated > 10 years [0]

Continued

Table 7. — *Soil-site properties influencing the four major soil factors and thus cherrybark oak growth (continued)*

Soil-site property	Soil-site condition and relative quality		
	Best	Medium	Poor
	Factor 3. Nutrient availability		
Geologic source	Mississippi River, Loess, Blackland [3]	Mixed Coastal Plain and other [1]	Coastal Plain [0]
Past use and present cover	Undisturbed; near-virgin forest cover, cultivated < 5 years [5]	Moderate cultivation; cultivated 5-10 years, or open with grass [3][3]	Intensive cultivation; cultivated > 10 years, or open and bare [1][3]
Organic matter (A-horizon)	> 2% [5]	1-2% [3]	< 1% [0]
Depth of topsoil (A-horizon)	> 6″ or no profile development [5]	3-6″ [2]	< 3″ [-3]
Soil age	Young, no profile development (Entisols) [2]	Medium, moderate profile development (Inceptisols) [1]	Old, well-developed profile, leached (Alfisols) [0]
pH (in rooting zone)	4.5-5.5 [5]	5.6-7.5; < 4.5 [3]	> 7.5 [Unsuitable]
	Factor 4. Aeration		
Soil structure (in rooting zone)	Granular, porous; single-grained; or massive (if sandy, loamy, or silty) [8]	Prismatic; blocky [4]	Massive (if clayey); platy [0]
Swampiness	Wet in winter only [8]	Wet January-July [4]	Waterlogged all year [Unsuitable]
Mottling	None to 18″ depth [8]	None to 8″ depth [4]	Mottled to surface [-2]
Soil color (A-horizon)	Black, brown, red [7]	Yellow, brownish-gray [4]	Gray [-2]

---

[1] Each bracketed number indicates the site quality rating (SQR) of a particular soil-site condition.

[2] If the soil is a sand or loamy sand, then [-10].

[3] If cultural practices included annual fertilization, then [4].

Table 8.—*Expected stand and production data for cottonwood at various ages by site class*

			STAND DATA				EXPECTED PRODUCTION PER ACRE					
							VOLUME				DRY MATTER (TONS)[e]	
									M Bd. ft.[d]			
Site index range (Ft @ 30 yrs)	Site class	Thinning	No. trees per acre	Mean ht (ft.)[a]	Mean dia (in.)	Basal area (ft²)	Cu ft[b]	Cords[c]	Doyle	Int. ¼	Branches	Stems
						AT AGE 5 (Before thinning)						
80–90	III (Low)	None	325 ± 20	30 ± [illegible]	4 ± 1	30 ± [illegible]	250 ± 80	[illegible] ± 3		—	[illegible]	1
100–110	II (Med.)	1/2 BA	325 ± 20	35 ± [illegible]	6 ± 1	65 ± 16	[illegible]	8 ± [illegible]			[illegible]	[illegible]
120–130	I (High)	1/2 BA	325 ± 20	45 ± [illegible]	7 ± 1	85 ± 16	1305 ± 310	17 ± [illegible]			[illegible]	[illegible]
						AT AGE 10 (Before thinning)						
80–90	III (Low)	1/2 BA	310 ± 20	4[illegible]	7 ± 1	80 ± 10	1430 ± 250	16 ± [illegible]			[illegible]	13
100–110	II (Med.)	1/3 BA	155 ± 15	60 ± [illegible]	10 ± 1	85 ± 10	2185 ± [illegible]	21 ± 3			[illegible]	[illegible]
120–130	I (High)	1/3 BA	[illegible]	80 ± [illegible]	15 ± 2	140 ± 20	[illegible]	36 ± [illegible]			[illegible]	[illegible]
						AT AGE 15 (Before thinning)						
80–90	III (Low)	[illegible] BA	14[illegible] ± 15	60 ± [illegible]	[illegible] ± 1	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]
[illegible]	II (Med.)	[illegible] BA	90 ± [illegible]	80 ± [illegible]	[illegible] ± 2	8[illegible] ± 10	2510 ± 360	[illegible] ± 1			[illegible]	[illegible]
120–130	I (High)	1/3 BA	90 ± [illegible]	100 ± [illegible]	[illegible] ± 2	125 ± 15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
						AT AGE 20 (Before thinning)						
80–90	III (Low)	None	85 ± [illegible]	70 ± [illegible]	[illegible] ± 2	[illegible]	1600 ± [illegible]	18 ± [illegible]			[illegible]	[illegible]
[illegible]	II (Med.)	None	[illegible] ± 10	90 ± [illegible]	16 ± 2	[illegible] ± 10	[illegible]	[illegible] ± 4	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	I (High)	[illegible] BA	[illegible] ± 10	110 ± [illegible]	18 ± [illegible]	[illegible] ± 20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
						AT AGE 30						
80–90	III (Low)	CC	7[illegible] ± 10	85 ± [illegible]	14 ± 2	80 ± 10	2730 ± 450	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	II (Med.)	CC	[illegible]	10[illegible]	20 ± [illegible]	110 ± 20	[illegible]	48 ± [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	I (High)	CC	[illegible]	12[illegible] ± 5	28 ± [illegible]	[illegible] ± 25	[illegible] ± 615	68 ± [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
						NET PRODUCTION AT AGE 30 (Clearcut at age 30 plus previous thinnings)						
80–90	III (Low)						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	II (Med.)						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	I (High)						[illegible]	[illegible] ± 11	[illegible]	[illegible]	[illegible]	[illegible]

[a] Dominants and codominants.

[b] From McBride and Krinard's (1971) volume equations for merchantable volume outside bark to a 3-inch top.

[c] Cords = cu ft volume ÷ 80.

[d] From girard tree volume tables ([illegible]) for gross tree volume outside bark to a [illegible]-inch top (Grosenbaugh [illegible]; Putnam *et al.* 196[illegible]). Remaining tops, often [illegible] and [illegible] included in [illegible] production.

[e] From M[illegible] dry matter equations.

APPENDIX

Explanation of Terms

The explanation of terms is for use with Tables 1-7. For terms not defined, see *Glossary of Soil Science Terms* (1975) or *Soil Survey Manual* (1951).

Depth of Topsoil or A-Horizon: Depth of surface soil or depth to B-horizon. Topsoil depth can be distinguished by a rather abrupt change in soil color or texture. Topsoil is ordinarily darker in color and coarser in texture than subsoil.

Geologic Source: Geologic origin of the soil or the physiographic area in which the soil occurs. Soils in the Mississippi River, Loess, and Blackland areas are generally high in native fertility. Coastal Plain soils are relatively low in native fertility and have low pH (<5.5); when mixed with other geologic sources that are more fertile, they usually have a pH higher than 5.5.

Mottling: Spots or blotches of different color (normally gray, yellow, or light brown) interspersed within the dominant color of the soil. Mottling is usually caused by poor internal drainage and poor aeration.

Organic Matter: The organic fraction of the soil: includes plant and animal residues at various stages of decomposition. Soils with high organic matter content are generally dark in color and have visible humus particles, while soils with low organic matter content are light colored.

Pans: Layers in the soil that are strongly compacted, hardened, or very high in clay content. Pans often restrict root penetration and vertical movement of soil water.

Artificial Pans (Plowpans or Pressure Pans): A subsurface soil layer that is compacted as a result of normal tillage operations or other artificial means. These pans can normally be detected as resistance to downward movement of a soil auger and by the tightly compacted, dense, and often dry soil condition.

Inherent or Genetic Pans: A natural subsurface soil layer that is harder or more cemented or brittle than the soil above and below it. Often called claypan or fragipan.

Water Table Depth: The average depth to a non-stagnant "true" water table during the growing season. Water table depth can often be determined by soil boring to free water or by observing free water elevations in nearby streams, lakes, ponds, etc., in relation to the elevation of the site.

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Additional keywords: Site index, soil properties, *Populus deltoides, Liquidambar styraciflua, Platanus occidentalis, Fraxinus pennsylvanica, Quercus nuttallii, Q. nigra, Q. phellos, Q. falcata* var. *pagodaefolia.*

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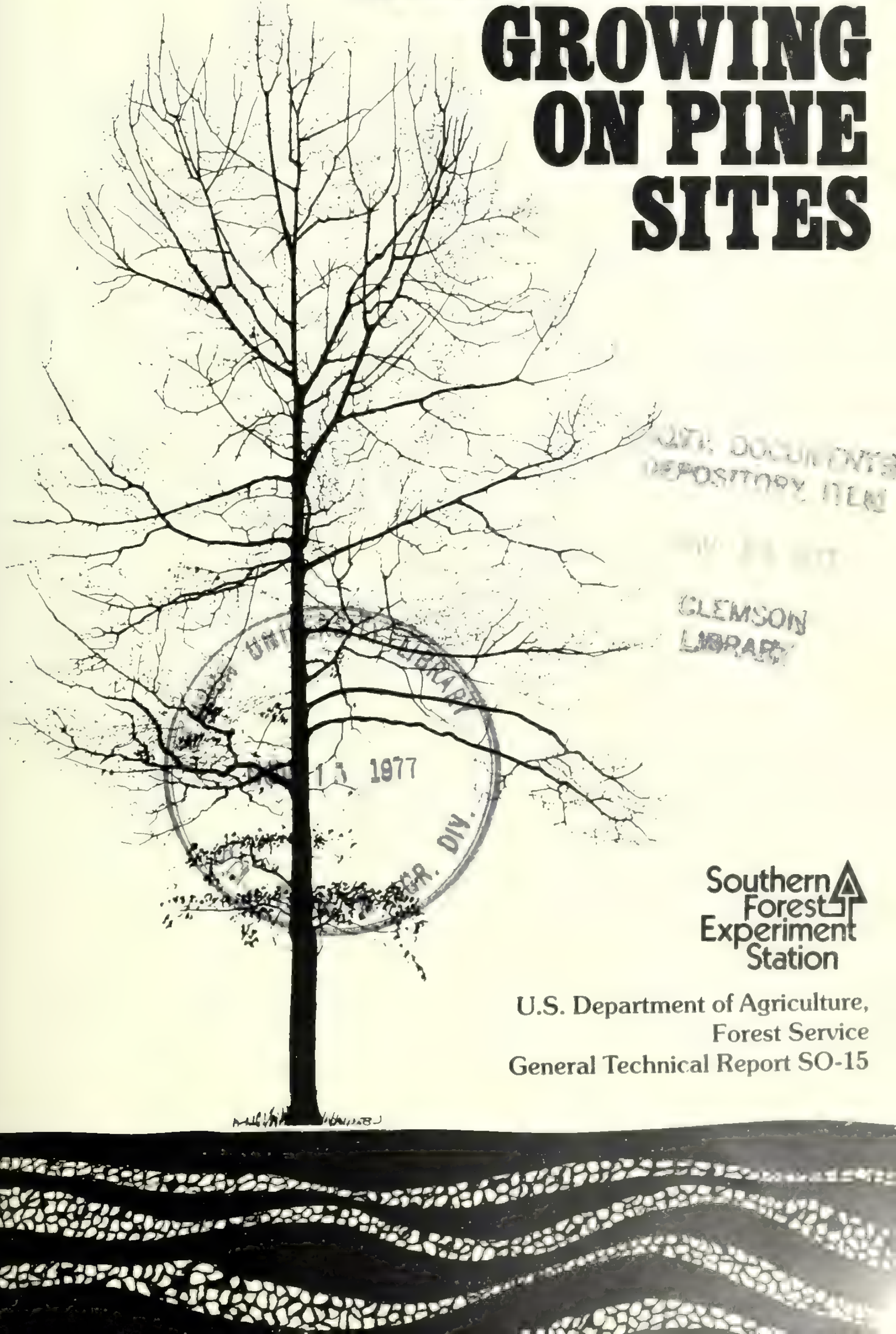

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Summary

This publication illustrates and describes 26 hardwood species or varieties, including 16 oaks and hickories, with photographs of leaves, bark, buds, flowers, and fruits. Line drawings feature the winter silhouette of each species and a key is included to assist in identification.

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Identifying Hardwoods Growing On Pine Sites

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Overview of Southern Hardwoods

Throughout the South some 49 billion cubic feet of small, low-quality hardwoods are growing on southern pine sites[*] (Staff, For. Resour. Res. Work Unit 1976). This material is usually wasted; if the site is prepared for regeneration to pine, the hardwoods there are destroyed. Research is underway to find economical methods of harvesting and utilizing these hardwoods. The descriptions, key, and illustrations in this book should help wood utilization researchers, especially those new to the South, to identify the most prevalent hardwood species on southern pine sites (Table 1).

---

[*] For the purposes of this paper, pine sites are defined as forested uplands, excluding those growing cove-type hardwoods, that are supporting southern pine or show evidence such as stumps of its former occurrence.

Table 1.—*Important hardwoods on southern pine sites, ranked according to percentage of total hardwood volume*[1]

Species		Percent
Sweetgum	*Liquidambar styraciflua* L.[2]	13.2
White oak	*Quercus alba* L.	12.3
Hickory	*Carya* spp.	8.5
Southern red oak	*Quercus falcata* Michx.	8.1
Post oak	*Quercus stellata* Wangenh.	7.0
Yellow-poplar	*Liriodendron tulipifera* L.	7.0
Black tupelo	*Nyssa sylvatica* Marsh.	5.5
Water oak	*Quercus nigra* L.	4.7
Black oak	*Quercus velutina* Lam.	4.0
Scarlet oak	*Quercus coccinea* Muenchh.	3.6
Red maple	*Acer rubrum* L.	3.6
Chestnut oak	*Quercus prinus* L.	2.9
Northern red oak	*Quercus rubra* L.	2.4
Laurel oak	*Quercus laurifolia* Michx.	1.4
Elm	*Ulmus* spp.	1.4
Cherrybark oak	*Quercus falcata* var. *pagodaefolia* Ell.	1.2
Ash	*Fraxinus* spp.	.9
Sweetbay	*Magnolia virginiana* L.	.6
Shumard oak	*Quercus shumardii* Buckl.	.2
Hackberry	*Celtis* spp.	.1
Other hardwoods	including blackjack oak (*Quercus marilandica* Muenchh.)	11.4
Total hardwoods		100.0

[1] Percentages were derived from Staff, For. Resour. Res. Work Unit (1976).

[2] Nomenclature used herein follows Little (1953).

Hickories have alternate compound leaves with 5 to 13 leaflets. The are monoecious; that is, the stamens and pistil are borne in separat flowers on the same plant. Flowers generally develop after the leaves ar three-fourths to full grown. Staminate flowers are in catkins, which occu on last year's wood and usually have three branches. The stalkless pistillate flowers are in several-flowered spikes at the apex of the curren season's growth. Catkins last from 10 days to 3 weeks and are usuall not useful in distinguishing the species. The fruit, however, is widel used for identification. The husk may be very thin (about 1 mm), moderately thick (3 to 5 mm), or very thick (more than 5 mm). Similarly, the shell may be thin, moderately thick, or very thick. The meat varies from sweet to bitter. Upon drying, the husk usually separates along sutures and frees the nut. In some species the husk partly splits at the sutures but still encloses the nut when it falls. Such nuts are usually sterile, because the meat is seldom filled out.

For identification purposes use nuts from the ground with caution; if more than one species grows in the vicinity, the fruits could be mixed. Also some trees shed defective or sterile fruits early, and these fruits are often different in shape and size from typical fruit.

Hickories are generally divided into true hickories, which have overlapping (imbricate) bud scales, and pecan hickories, which have valvate bud scales. True hickories are divided into those with tight bark and those with loose bark. **Mockernut Hickory,** *Carya tomentosa* Nutt., a tight bark species, has very pubescent leaves, large buds, and a thick husk over a large nut. **Pignut Hickory,** *C. glabra* (Mill.) Sweet, also a tight bark hickory, has three to nine glabrous leaflets and a tardily dehiscing husk about 3 mm thick. **Shagbark Hickory,** *C. ovata* (Mill.) K. Koch, is one of the few species with bark in thin, loose plates. It has small buds and usually has five leaflets. **Bitternut Hickory,** *C. cordiformis* (Wangenh.) K. Koch, belongs to the pecan hickory group and has yellow buds with valvate scales. It also has tight bark, thin four-winged husks, thin shells, and bitter meat.

Oaks are also monoecious, and staminate flowers are in drooping catkins, which consist of a central, flexible axis with sessile, apetalous and pubescent flowers. They are most abundant on the developing new twigs. Although catkins vary among oaks, they are usually not used as distinguishing characteristics because they last only 2 to 3 weeks. Pistillate flowers occur on wood of the previous season and in leaf axils of twigs. In red oaks, however, pistillate flowers on current twigs do not mature until the second fall.

The fruit, a nut or acorn, consists of the seed enclosed in a shell. The nut is seated in a cup consisting of many scales. At maturity nuts are shed from the tree by shrinkage of the cup (dehydration). Considerable variation in mature acorn size occurs among trees of a species, notably in water oak, willow oak, and white oak.

Differences in foliage within a species also complicate identification.

Apparently because lower leaves receive less sunlight they differ in size and appearance from those in the middle or upper crown. Most taxonomists prefer a specimen from the upper half of the crown because they consider leaves from this area typical for the species. To get such specimens easily, use a tree pruner and take leaves from at least 20 to 30 feet off the ground or collect them from freshly felled trees. Moreover, foliage of seedlings and small saplings often differs from that of mature trees, and spring and summer growth flushes on the same branch often appear markedly different. This seasonal variation has been noted for many oaks, including laurel, post, blackjack, and especially water oak. For example, by late March or April, water oak leaves reach their normal size and shape — obovate with a wavy apex; the second flush of growth, which starts in late April or May, produces lobed leaves.

Identification is further complicated because hybrids commonly occur among the oaks.

The oaks are divided into two main groups: the white oaks and the red (or black) oaks. The white oaks have leaves with rounded lobes and no bristles; acorns mature the first fall, and the inner surface of the shell is glabrous. White oak, chestnut oak, and post oak belong to this group. The red oak group is characterized by bristle-tipped leaf lobes in such species as Shumard, southern red, northern red, cherrybark, and black oak. The red oak group also includes non-lobed species such as water, laurel, and willow oak, which usually have entire margins. Blackjack oak leaves usually lack lobes and bristles, but leaves with terminal lobes occasionally occur and may have one bristle per lobe. Acorns mature the second fall, and the inner surface of the shell is pubescent.

Southern Red Oak, *Quercus falcata* Michx., and its variety **Cherrybark Oak,** *Q. falcata* var. *pagodaefolia* Ell., have almost identical acorns, but they can be distinguished by other characteristics. The leaf base of southern red oak is somewhat bell-shaped, but that of cherrybark is not. Southern red oak forms heavy ridges of bark; cherrybark does not.

The distinctive feature of **Black Oak,** *Q. velutina* Lam., is its yellow-orange inner bark. Its leaves take three forms. Seedlings to small saplings have a "bear-paw" leaf with only a suggestion of lobing. Lower leaves on large trees also have little lobing, but leaves from the middle and upper crown are clearly lobed. The uppermost leaves, which have seven lobes and deep sinuses, are usually illustrated as typical.

Scarlet, *Q. coccinea* Muenchh., **Northern Red,** *Q. rubra* L., and **Shumard Oak,** *Q. shumardii* Buckl., are difficult to distinguish. Northern red oak leaves have shallow sinuses and a dull-green upper surface with little or no pubescence in the vein axils on the underside. Shumard oak leaves have a glossier surface, shallow to deep sinuses that are usually wider than the adjacent lobes, and definite hairiness at the vein axils. The sinuses of scarlet oak are also usually wider than their adjacent lobes, which are usually toothed. Both Shumard and scarlet oak have outstanding fall coloration.

Blackjack Oak, *Q. marilandica* Muenchh., can be recognized by its leathery, usually entire, broadly obovate leaf, which has a rusty undersurface. The branches are stout, irregular, gnarled, drooping to horizontal

Laurel Oak, *Q. laurifolia* Michx., and **Water Oak,** *Q. nigra* L., are similar in size and shape, but water oak has oblong-obovate or spatula-shaped leaves gradually narrowed to a wedge-shaped base. Laurel oak leaves are elliptic to oblong-ovate. Laurel oaks tend to shed leaves late and thus may retain about 30 to 50 percent of their lower leaves afte water oaks are bare. Some recent authors separate the laurel oaks into two species, upland laurel oak, *Q. hemisphaerica* Bartr., and swamp laurel oak, *Q. laurifolia* Michx.

White Oak, *Q. alba* L., has a thin, light green leaf with a light glaucous bloom at maturity; it is oblong or ovate, with rounded lobes and three to five narrow sinuses extending nearly to the mid-rib. The cup scales of the acorn-cup are heavy and distinct.

Post Oak, *Q. stellata* Wangenh., has stout, irregular branches. The leathery leaves are usually five-lobed; usually the two side lobes are at right angles to the central axis, thus forming a cross-shaped leaf.

Chestnut Oak, *Q. prinus* L., resembles swamp chestnut oak, *Q. michauxii* Nutt., a commercially important tree southwide. Chestnut oak is primarily a northeastern tree, extending into the South along the Appalachian highlands into northern Georgia and Alabama where its range overlaps that of swamp chestnut oak, and its leaves lack the dense pubescence found on those of swamp chestnut oak.

Common elms include **American Elm,** *Ulmus americana* L., and **Winged Elm,** *U. alata* Michx. Both bloom after a freeze breaks dormancy. For example, if a killing frost occurs in the last week of November or the first week of December, American elm will bloom the first week of January. If no killing frost occurs by early December, American elm may not bloom until the third week of January. Winged elm usually blooms 10 days to 2 weeks later than American elm. Small winged elm trees frequently have a corky outgrowth on opposite sides of twigs at least 3 years old. Mature trees often lack this characteristic. The American elm leaf has unequal basal lobing and pubescent or ciliate samaras about 12 mm in diameter; winged elm has a smaller leaf with round to acute leaf bases and a very ciliate samara about 8 mm long.

Young **Sugarberry,** *Celtis laevigata* Willd., and Hackberry, *C. occidentalis* L., trees are readily recognized by a whitish to light gray bark dotted with small corky warts. Older trees often have relatively smooth, light to medium gray bark. Leaf margins of sugarberry are usually entire or indistinctly toothed; the upper half of hackberry leaves are usually conspicuously serrate. Both species produce tiny flowers on the new growth when the leaves are about half normal size. The fruit of sugarberry is orange-red to black; that of hackberry is dark red to nearly black at maturity.

Yellow-poplar, *Liriodendron tulipifera* L., or tulip tree, has alternate, four- to six-lobed leaves with truncate to distinctly notched apices, a unique feature among American trees. The flowers are tulip-like with red markings on a greenish-yellow background. The fruit is a cone-like aggregate of samaras.

Sweetbay, *Magnolia virginiana* L., produces moderate-sized trunks on uplands or numerous pole-like suckers in branch bottoms. It is evergreen in the southern part of its range and deciduous in the northern portion. A wind blowing in the crown will expose the silvery underside of the leaves. The white flowers, about 5 to 10 cm in diameter, open for the first time about 3 p.m. and close about 9 p.m. They reopen the next morning and shed their stamens. The fruit is a green pickle-like aggregate of follicles that splits open to reveal red seeds. Sweetbay and yellow-poplar, both members of the Magnolia family, have stipule scars circling the twigs.

Sweetgum, *Liquidambar styraciflua* L., or redgum, is easily recognized by its alternate, star-shaped, palmately lobed leaves. Some trees have corky outgrowths on the small branches. Its flower consists of several round clusters of stamens arranged in a raceme and a stalked pistillate head that develops into a spiny, woody fruit containing many seeds.

Red Maple, *Acer rubrum* L., has simple, opposite leaves that are usually glaucous and pubescent. The flowers appear in early February and the fruit is a double samara. The variety *A. rubrum* var. *drummondii* (Hook. and Arn.) Sarg., which has densely matted white hairs on the undersides of young leaves, grows in swamps throughout the South. Leaves may have three to five lobes, but southern trees are predominantly three-lobed. For this reason, some authors recognize the southern form as *A. rubrum* var. *tridens* Woods.

The leaves of **Black Tupelo** (blackgum) *Nyssa sylvatica* Marsh., are alternate, elliptical to obovate, and become spotted early in their development, turning purplish in September before their early shedding. The flowers are small, inconspicuous, and produce a blue-black fruit.

Two of the most common ashes are **White Ash,** *Fraxinus americana* L., and **Green Ash,** *F. pennsylvanica* Marsh. The most reliable distinction between the two species appears to be samara differences. White ash has a plump, short seed end with the wing practically terminal, whereas green ash has a slender seed end and the wing extends more than halfway down the seed end. White ash usually has a rounded leaflet base, but green ash has wedge-shaped leaflet bases. The undersurfaces of fresh white ash leaves are white, but the color is difficult to detect on dry specimens. Green ash leaves are green on both surfaces, although somewhat paler on undersurfaces.

Key To Hardwoods

The key is composed of paired statements, one true and one fal for any given specimen. The guide numbers at the end of statements a used to locate the next pair. Follow the true statements until you come a common name. If you have made no mistake in interpreting the pair statements, you should arrive at the correct identity of the specime Then check the text and illustration.

1. Leaves compound, with blades divided into leaflets . . . .
1. Leaves simple, blades not divided into leaflets . . . .
    2. Leaves with opposite arrangement on twigs . . . .
    2. Leaves with alternate arrangement on twigs . . . .
3. Leaflets with rounded bases, conspicuously whitish below when fresh; seed end of samara thickened, wing terminal only . . . . **White As**
3. Leaflets with wedge-shaped bases, green below; wing terminal and extending about half the length of the seed . . . . **Green As**
    4. Buds valvate; buds, fruits, and lower surface of leaflets covered with yellow glandular scales; fruit winged on upper half of husk suture, husk thin, shell thin, meat bitter . . . . **Bitternut Hicko**
    4. Buds imbricate, composed of overlapping scales . . . .
5. Leaflets typically 5, glabrous except for a few hairs on rachis and midribs; bark shaggy . . . . **Shagbark Hicko**
5. Leaflets 7 . . . .
    6. Leaflets densely tomentose; bark tight, in diamond-shaped pattern; husk very thick, shell thick, meat sweet . . . . **Mockernut Hicko**
    6. Leaflets usually glabrous; bark tight, in diamond-shaped pattern; husk moderately thick, shell thick, meat sweet, husk tardily dehiscent . . . . **Pignut Hicko**
7. Leaves essentially evergreen, large percentage staying on trees until bud expansion, dark green above, silky white pubescent below; flowers white, about 5 to 8 cm in diameter . . . . . . **Sweetba**
7. Leaves typically deciduous, or trees retaining some dead leaves to bud expansion . . . .
    8. Leaf margins entire . . . .
    8. Leaf margins lobed or toothed **1**
9. Leaves with rusty pubescence below, broadly obovate, leathery bases tapering to cordate or cuneate . . . . **Blackjack Oa**
9. Leaves essentially glabrous or with a few hairs in vein axils **1**
    10. Leaves shiny below, elliptic or rhombic to spatulate . . . . **Laurel Oa**
    10. Leaves dull green below **1**

11. Leaves elliptic to obovate, strongly veined with purple spots and discoloration in summer; fruit a drupe . . . . **Black Tupelo**

11. Leaves abruptly obovate, bases wedge-shaped, few lateral veins; fruit an acorn . . . . **Water Oak**

 12. Leaf margins toothed **13**

 12. Leaf margins lobed **16**

13. Margins indistinctly toothed, blades narrowly to broadly ovate, base unequal, apex long acuminate . . . . **Sugarberry**

13. Margins distinctly toothed **14**

 14. Teeth obtuse or rounded, leaf base wedge-shaped, stellate pubescent below . . . . **Chestnut Oak**

 14. Teeth sharp **15**

15. Leaves normally elliptic, veins prominent below, bases rounded; corky outgrowths on older branches, often lacking on large trees . . . . **Winged Elm**

15. Leaves broadly oval, pinnate veins distinct, margins doubly toothed, bases oblique, unequally rounded . . . . . **American Elm**

 16. Leaves palmately lobed **17**

 16. Leaves pinnately or apically lobed **18**

17. Leaves opposite, more or less glaucous and pubescent below; fruit a double samara . . . . **Red Maple**

17. Leaves alternate, glabrous below; fruit spherical, woody with spine-like projections; corky outgrowths on branches frequent . . . . **Sweetgum**

 18. Blades truncate to notched at apex, 4-lobed; fruit an aggregate of samaras; flower conspicuous, greenish-yellow with red markings . . . . **Yellow-poplar**

 18. Blades with acute to obtuse apices **19**

19. Blades apically 3-lobed **20**

19. Blades pinnately lobed **21**

 20. Blades broadly obovate, base rounded, rusty pubescent below . . . . **Blackjack Oak**

 20. Blades narrowly obovate, base wedge-shaped, mostly glabrous . . . . **Water Oak**

21. Leaves with rounded lobes **22**

21. Leaves with bristle tips to lobes and lateral teeth **23**

 22. Leaves with 7 to 9 lobes, divided nearly to the midrib, whitish below . . . . **White Oak**

 22. Leaves with 5 unequal lobes, upper lateral pair larger, squarish, at right angles to midrib, crosslike in appearance, pubescent below . . . . **Post Oak**

23. Leaves pubescent below, whitish to tawny **24**

23. Leaves glabrous below or with a few hairs on midrib and in vein axils **26**

24. Leaves with 7 to 9 lobes, terminal lobes long, strap-shaped, slightly curved, bases bell-shaped . . . . . . **Southern Red Oa**

24. Leaves with 7 to 11 lobes **25**

25. Leaves oblong, 7 to 11 lobes, base broadly wedge-shaped to truncate, secondary lobes rare; inner bark reddish . . . **Cherrybark Oa**

25. Leaves broadly oval, 7 to 9 lobes, each lobe with secondary bristle-tipped teeth; inner bark yellow-orange . . . . **Black Oa**

26. Upper leaf surface glossy green **27**

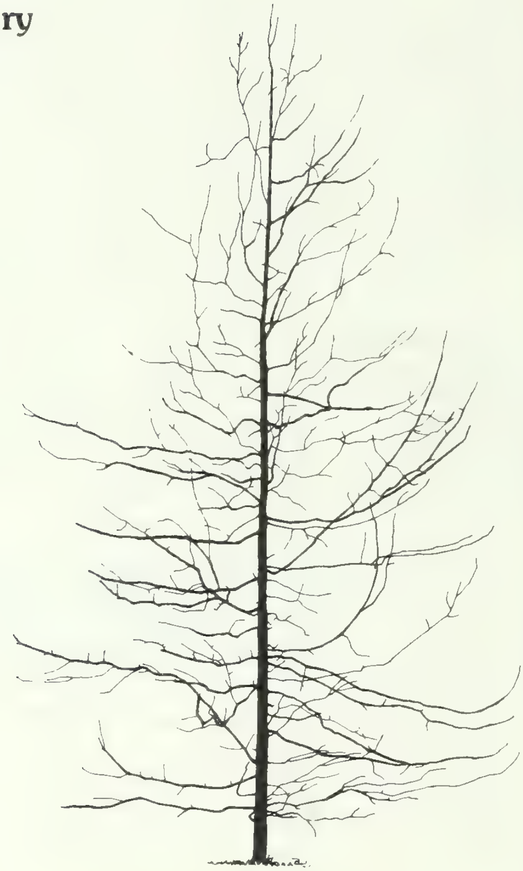
26. Upper leaf surface dull green, 7 to 9 lobes, 8 to 22 cm long, round sinuses extending less than half way to midrib . . . . **Northern Red Oak**

27. Leaves with 7 to 9 narrow lobes, sinuses extending more than halfway to midrib . . . . **Scarlet Oak**

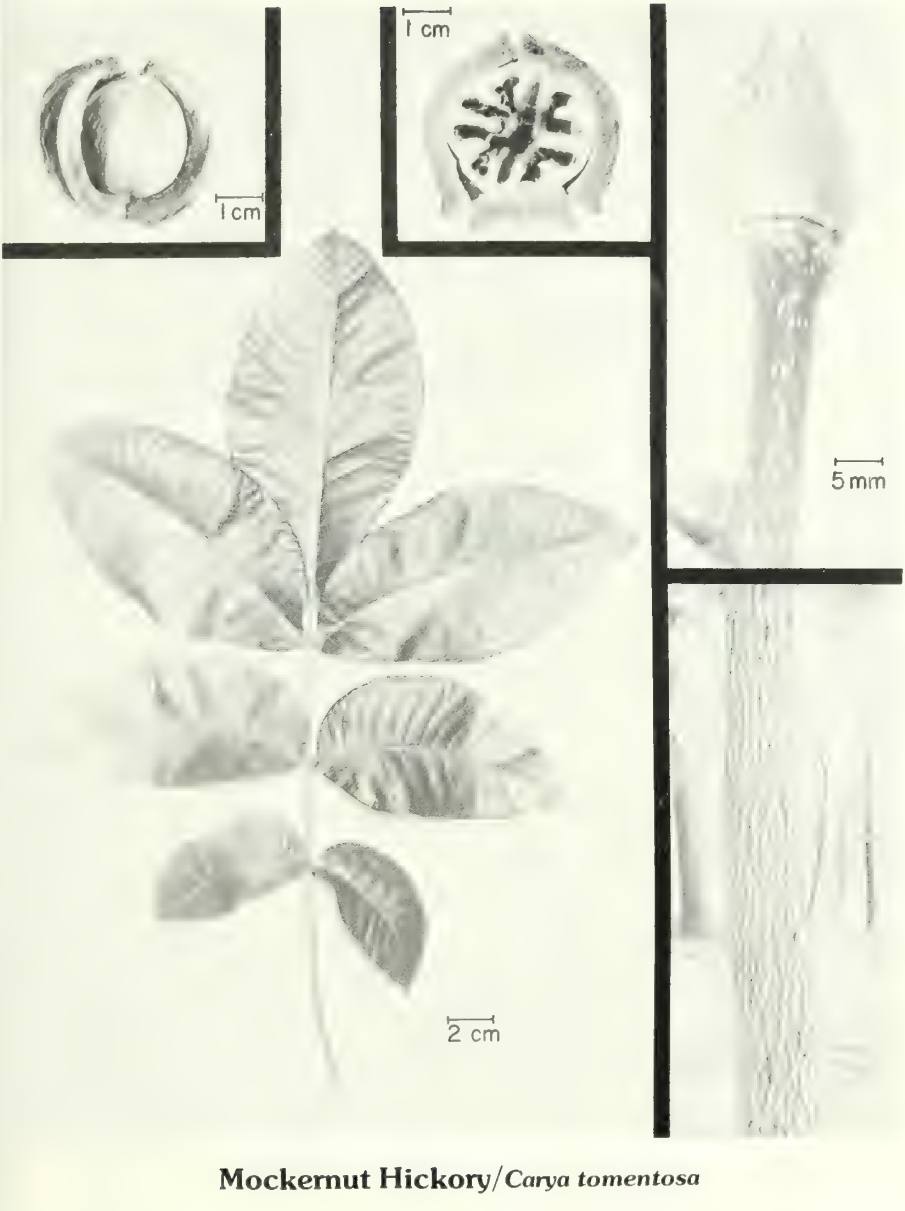
27. Leaves with 5 to 7 narrow lobes, rounded sinuses, extending about three-fourths of way to midrib . . . . **Shumard Oak**

Species Described and Illustrated

Mockernut Hickory
Carya tomentosa Nutt.



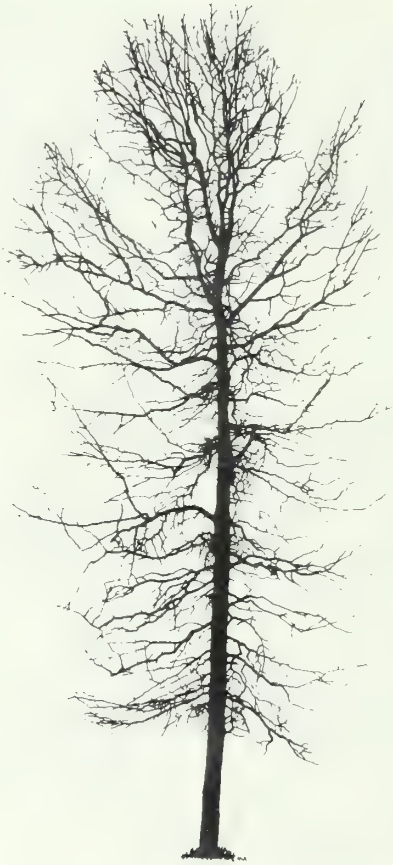
Bark grayish, tight, marked with distinct diamond-shaped ridges and furrows. **Branches** stout, drooping to spreading and ascending. **Twigs** 10 to 12 mm in diameter, conspicuous leaf scars. **Buds** (terminal) 10 to 15 mm long, 5 to 8 mm in diameter, scales imbricate. **Leaves** alternate, deciduous, odd-pinnately compound, 20 to 40 cm long with 5 to 7 drooping leaflets; yellow hairs and glandular hairs on lower leaflet surface, apex acuminate, margin finely serrate, base obtuse, on very short petiolules. **Flowers** unisexual, appearing in spring with developing leaves, staminate in 3-parted drooping catkins, pistillate terminal on new growth. **Fruit** subglobose to obovate, 3 to 5 cm in diameter, husk 1 cm thick, slow to open, shell of nut thick and hard, meat sweet.



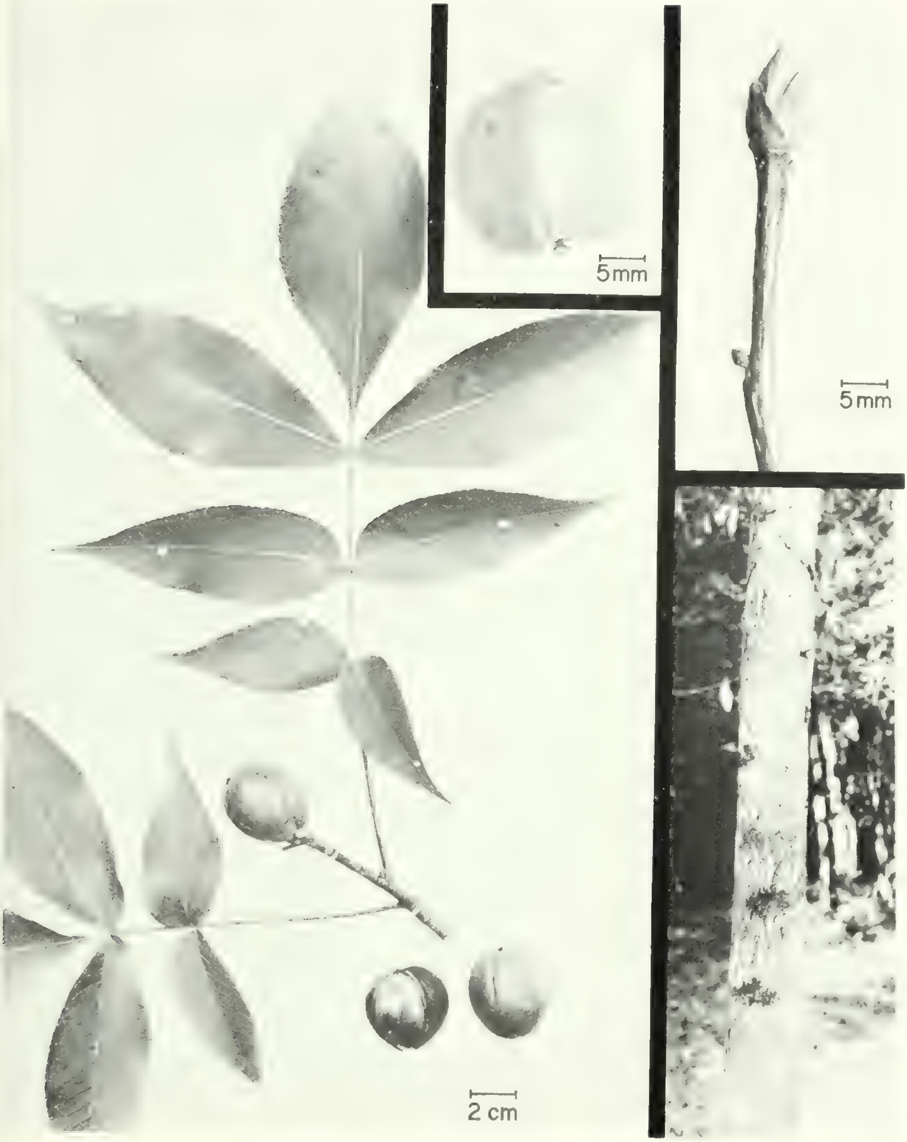
Mockernut Hickory/*Carya tomentosa*

Pignut Hickory

Carya glabra (Mill.) Sweet



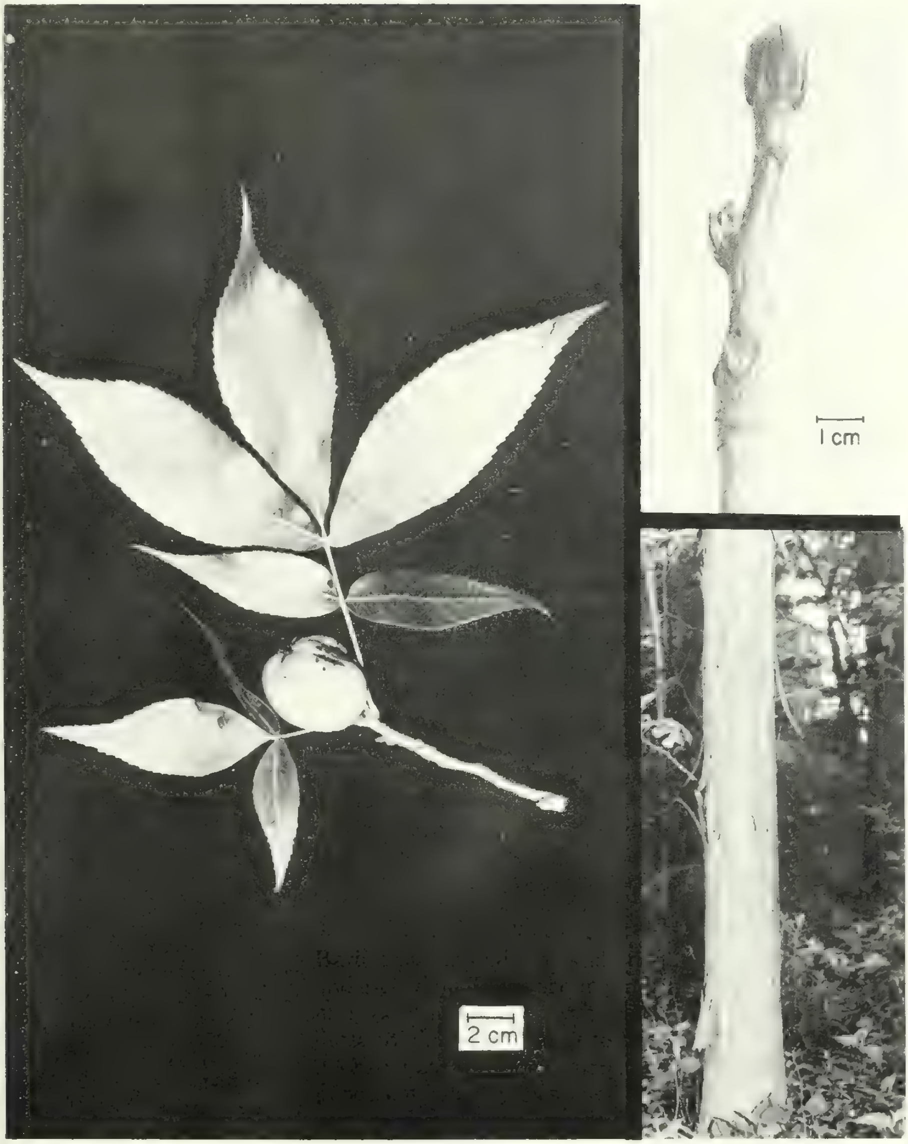
Bark light to dark gray, often blackish, rough and deeply furrowed. **Branches** stout, drooping to spreading. **Twigs** 3 to 5 mm in diameter, reddish brown, smooth. **Buds** ovoid, acute, glabrous, 8 to 12 mm long, scales imbricate. **Leaves** alternate, deciduous, odd-pinnately compound, 20 to 40 cm long, usually with 7 leaflets; upper pair and terminal largest, 10 to 15 cm long by 4 to 6 cm wide, broadly oval to slightly obovate. **Flowers** unisexual, staminate in 3-branched catkins appearing about the time of leaf maturity; pistillate terminal on new growth. **Fruit** oblong to obovoid to obpyriform, 30 mm in diameter by 35 mm long, husk about 3 mm thick, tardily dehiscent, shell of nut thick, meat sweet.



Pignut Hickory/***Carya glabra***

Shagbark Hickory
Carya ovata (Mill.) K. Koch

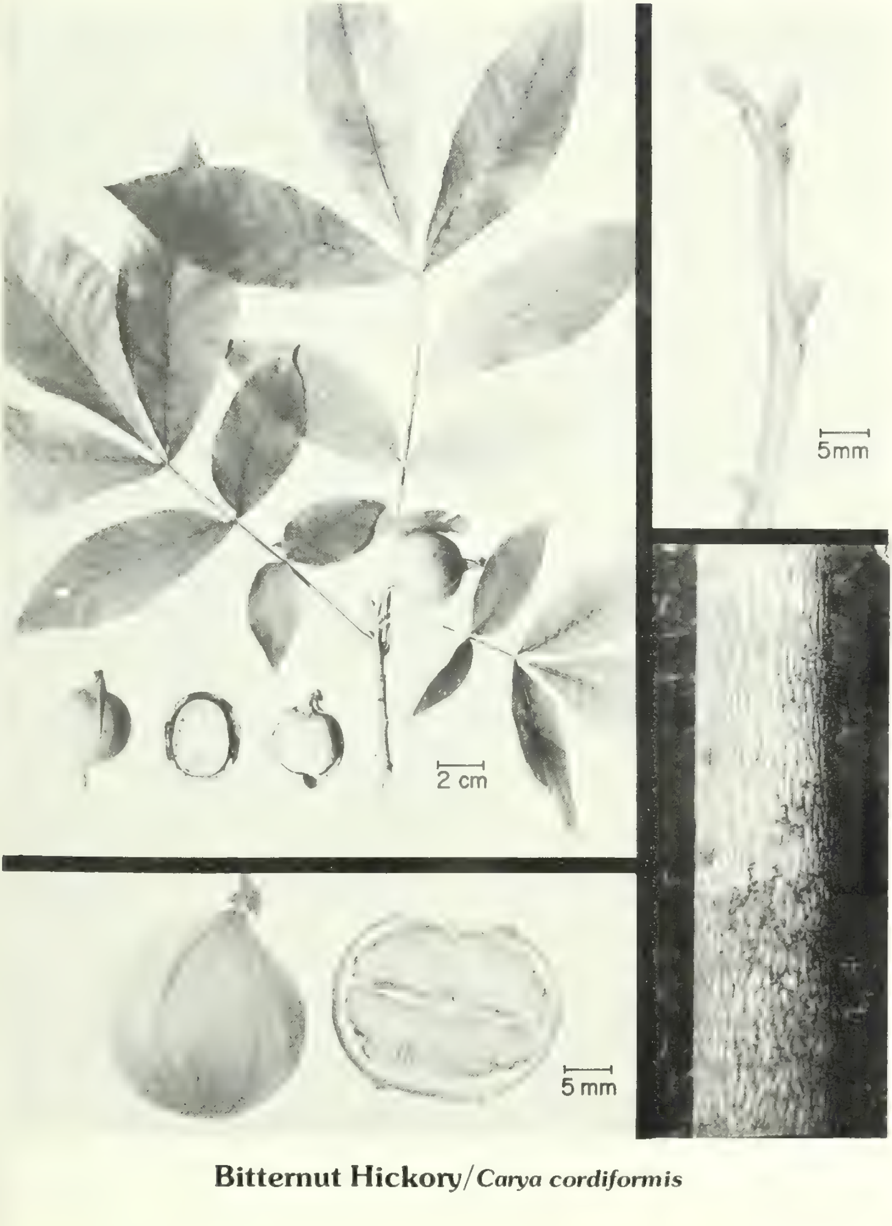
Bark smooth at first, then breaking into long, flat, irregular gray strips, to 5 mm thick, usually attached at the apex, free at the base. **Branches** stout, smooth, spreading to ascending. **Twigs** stout, orange-brown, leaf scars large. **Buds** (terminal), 10 to 20 mm long, 6 to 8 mm in diameter, scales imbricate. **Leaves** alternate, deciduous, odd-pinnately compound with 5 to 7 leaflets, usually 5 to 18 cm wide and 20 to 35 cm long; lateral leaflets ovate to ovate-lanceolate, terminal leaflet usually obovate, apices acute to acuminate, margins finely serrate, bases wedge-shaped, more or less yellow, pubescent below, gradually becoming glabrous with age. **Flowers** unisexual, appearing in spring with the developing leaves, staminate in 3-lobed catkins, pistillate on new growth. **Fruits** subglobose, 2.5 to 6 cm in diameter, husk 3 to 5 mm thick, shell of nut hard and moderately thin, meat sweet.



Shagbark Hickory/*Carya ovata*

Bitternut Hickory/
Carya cordiformis (Wangenh.) K. Koch

Bark brown to slate gray, smooth to lightly furrowed or with strongly interlaced ridges. **Branches** stiff, ascending, spreading. **Twigs** slender, glossy, often with yellow glands early in the season. **Buds** compressed, ovoid, 6 to 10 mm long, covered with yellow, valvate glandular scales. **Leaves** alternate, deciduous, odd-pinnately compound, 15 to 25 cm long with 7 to 9 leaflets, 7 to 15 cm long and 3 to 6 cm wide; lateral leaflets narrowly to broadly elliptic, terminal leaflet largest and usually obovate, apex acuminate, margin finely serrate, base wedge-shaped, with yellow glands on undersurfaces and on rachis. **Flowers** unisexual, staminate in 3 branched catkins appearing after leaves, pistillate terminal on new growth. **Fruit** ovate to subglobose, 2 to 3 cm in diameter, often slightly compressed, 4 winged on sutures from apex to middle of husk, husk thin, covered with yellow glandular scales, shell of nut thin, meat very bitter.

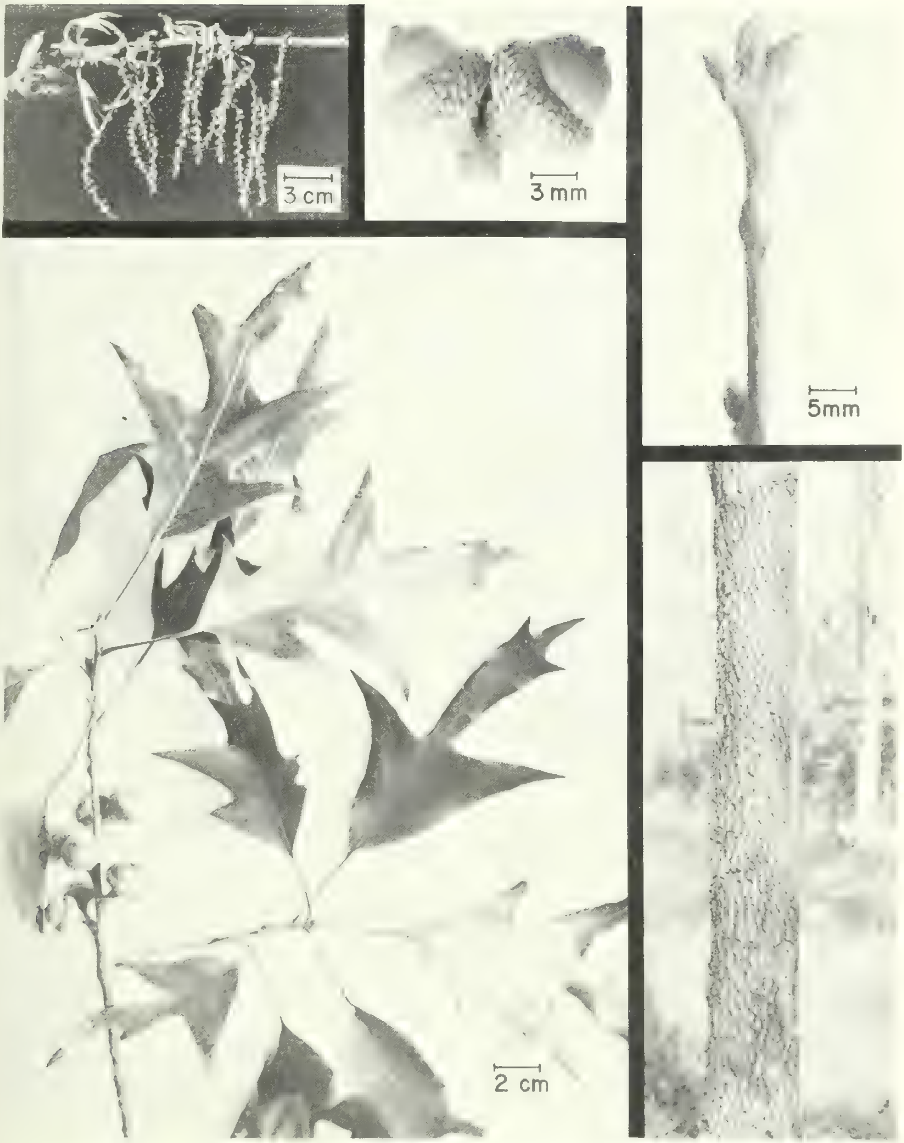


Bitternut Hickory/*Carya cordiformis*

Southern Red Oak

Quercus falcata Michx.

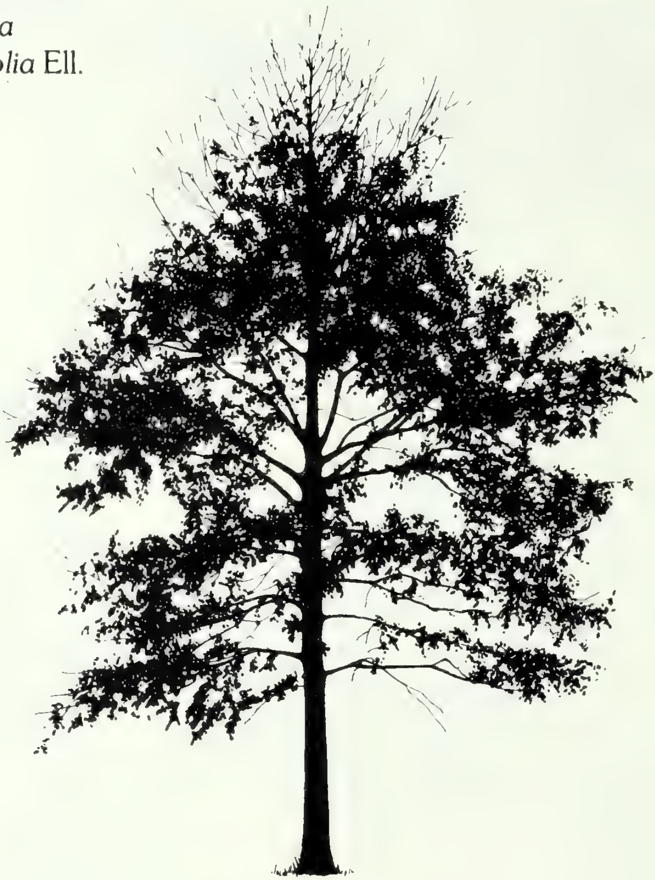
Bark dark brown to grayish black, divided by shallow, irregular fissures into broad ridges. **Branches** stout, spreading to ascending. **Twigs** 2 to 5 mm in diameter, dull reddish brown. **Buds** ovoid, angulate 8 to 13 mm long, apex acute. **Leaves** alternate, deciduous, simple, many remaining as dead foliage until spring, ovate to obovate with bell-shaped base, 10 to 28 cm long, 7 to 30 cm wide; with 3 to 9 lobes and margins with deep rounded sinuses, when 3-lobed, central lobe strap-shaped and toothed near the apex and side lobes acute to acuminate, somewhat falcate; permanently pubescent below, white at first, turning rust. **Flowers** unisexual, staminate in tomentose catkins as leaves unfold, pistillate in leaf axils on twigs. **Fruit** an acorn, small, spherical to hemispherical; cup 12 to 15 mm wide, shallow saucer-shaped, enclosing about one-fourth to one-half of the nut; nut 8 to 12 mm long.



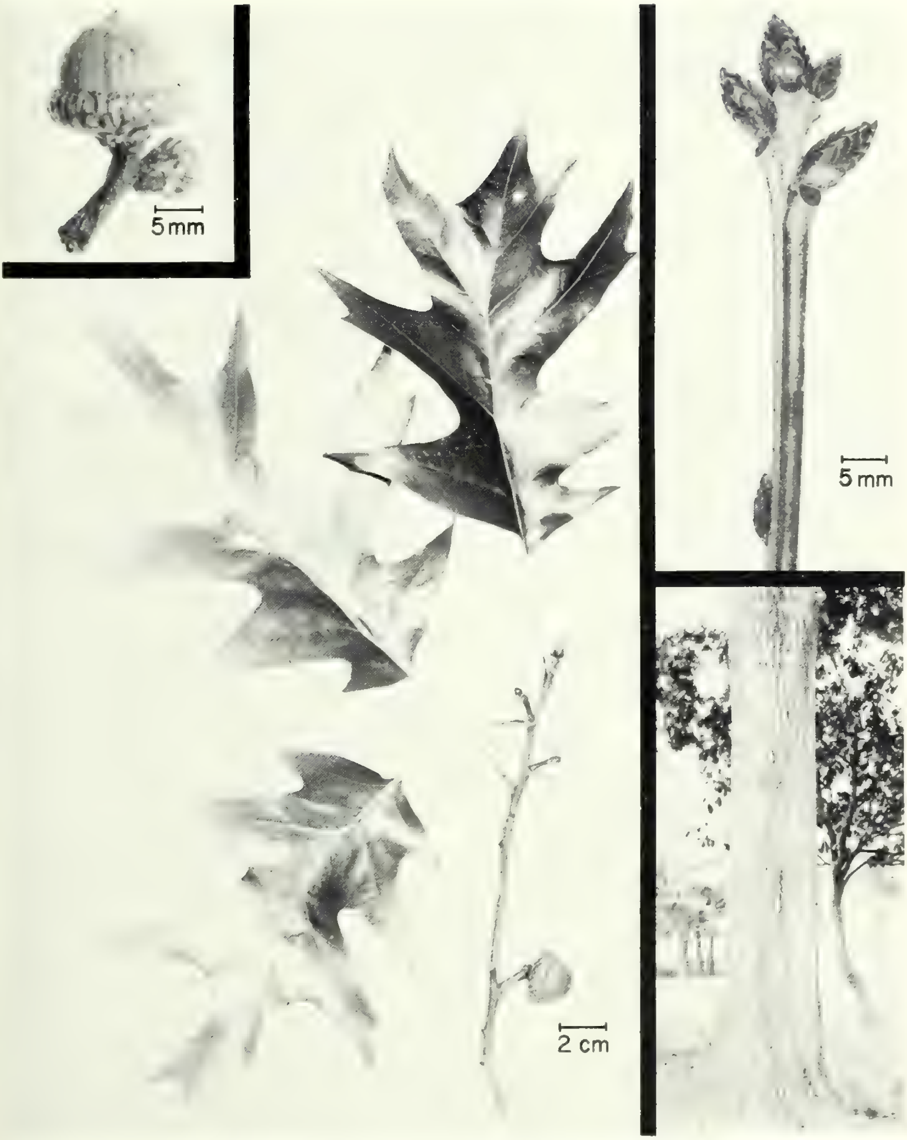
Southern Red Oak/*Quercus falcata*

Cherrybark Oak

Quercus falcata
var. *pagodaefolia* Ell.



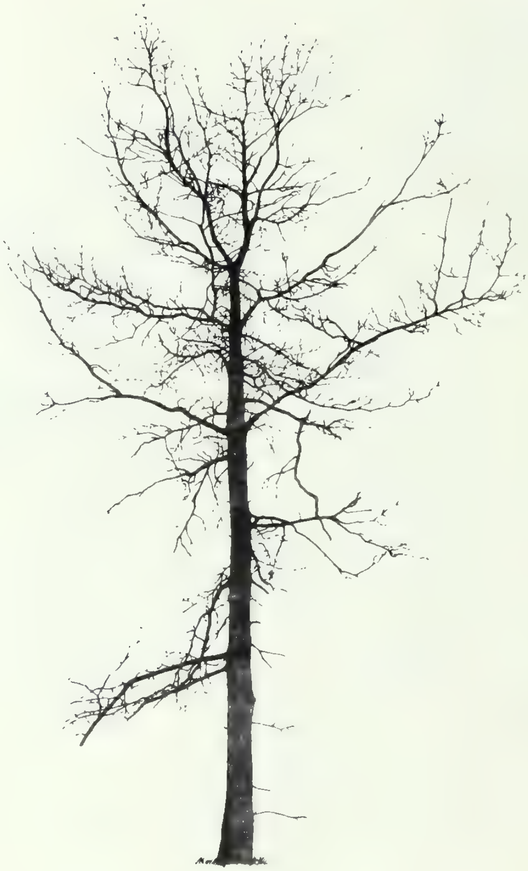
Bark dark gray to gray-black consisting of appressed scales in narrow flat ridges with shallow furrows. **Branches** stout, spreading to ascending. **Twigs** 2 to 4 mm in diameter, reddish, lightly fluted. **Buds** ovoid, 10 to 15 mm long, angled, scales pubescent with dark margins. **Leaves** alternate, tardily deciduous, persisting into December, simple, oval to oblong, 12 to 20 cm long, 7 to 8 cm wide; with 5 to 11 lobes, major lobes opposite each other, large rounded sinuses extending nearly to the midrib, margin entire with occasional bristle-tipped teeth near the apex of the lobes, dark green above, permanently pubescent below, sometimes thinly so, varying from white to rust color, especially on drying. **Flowers** as in *Q. falcata*. **Fruit** an acorn broader than tall; cups 12 to 15 mm wide; nut about 8 to 10 mm long, subglobose, flattened at base, rounded at apex.



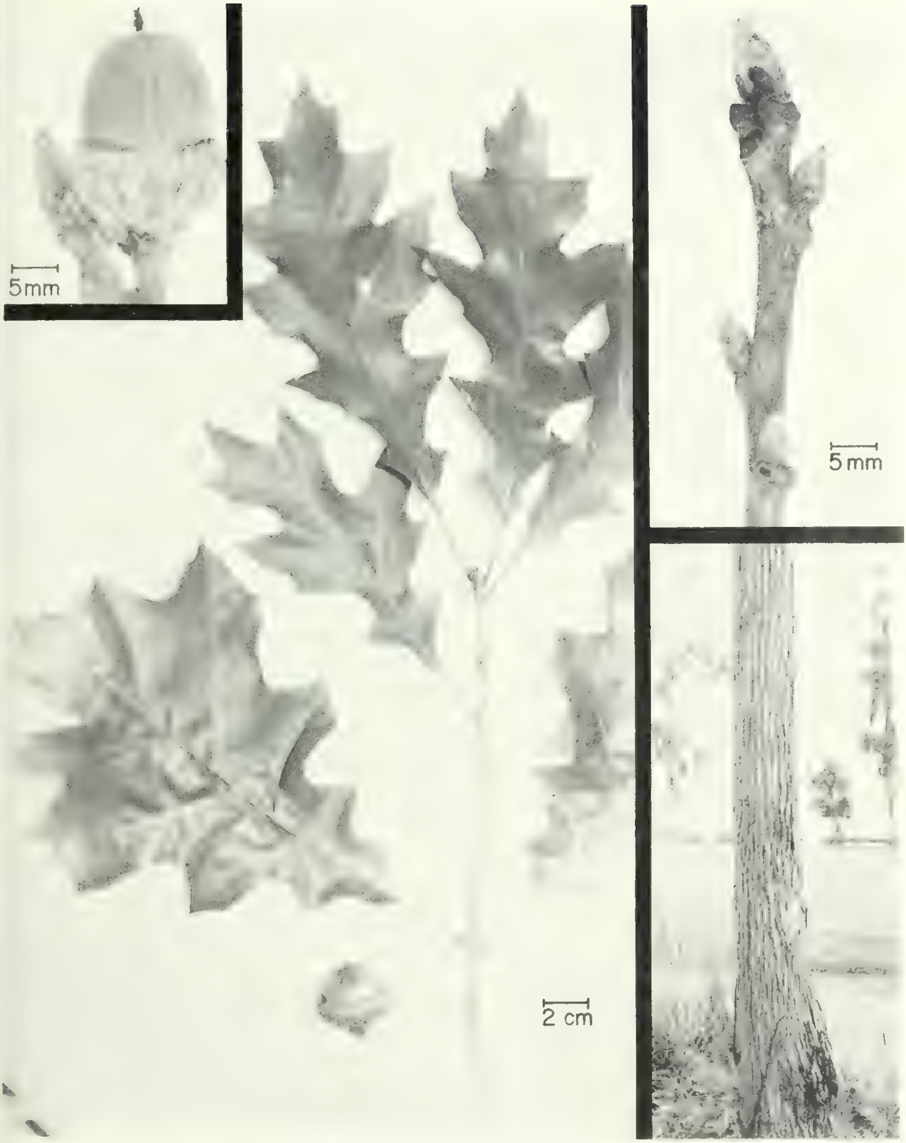
Cherrybark Oak/*Quercus falcata* var. *pagodaefolia*

Black Oak

Quercus velutina Lam.



Bark brownish-black on older trees, with thick, broad scaly ridges and deep furrows; inner bark yellow-orange — the only American oak with this feature. **Branches** stout, spreading to ascending. **Twigs** about 5 mm in diameter, reddish brown to dark brown, lightly fluted. **Buds** ovoid, 10 to 15 mm long, lateral buds sharply angled, scales ciliate, margin dark. **Leaves** alternate, deciduous, simple; membranous in seedlings and saplings to somewhat leathery in the middle to upper crown; lower leaves broadly elliptic to obovate, 15 to 30 cm long, 10 to 15 cm wide, entire to faintly lobed; middle crown leaves 10 to 20 cm long, 10 to 15 cm wide, distinctly 5 to 9 lobed with broad rounded sinuses with apical bristles on each lobe, upper-crown leaves oblong to obovate, 8 to 20 cm long, 8 to 15 cm wide; dark shiny green above, yellow scurfy pubescence on young leaves of middle and upper crown, petioles 4 to 6 cm long, yellow to reddish. **Flowers** unisexual; staminate catkins 7 to 15 cm long, pistillate on short tomentose peduncles. **Fruit** an oval to obovoid acorn 10 to 25 mm long; cup cup-shaped to conical enclosing about one-half of the nut.

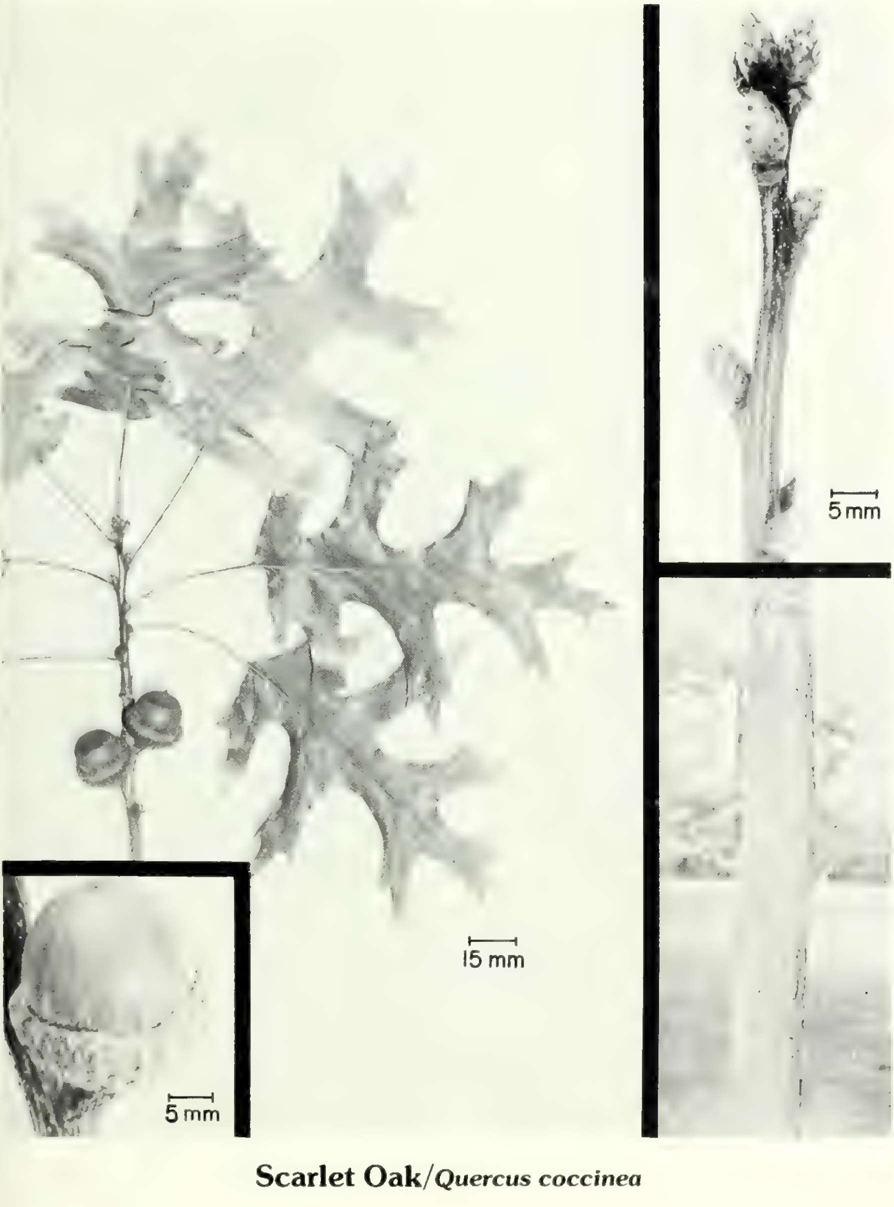


Black Oak/*Quercus velutina*

Scarlet Oak

Quercus coccinea Muenchh.

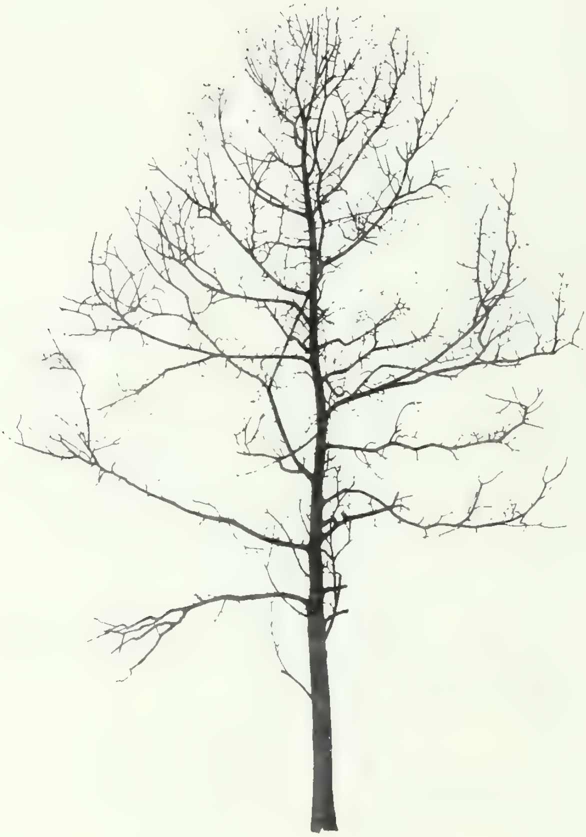
Bark dark grayish-black, divided into irregular fissures and scaly ridges. **Branches** stout, spreading to ascending. **Twigs** 3 to 4 mm in diameter, reddish, turning a dull red. **Buds** ovoid, acute, 5 to 7 mm long, covered with rounded, lightly pubescent scales. **Leaves** alternate, deciduous, simple; glabrous, except in axils of main veins on underside, oval to slightly obovate, 8 to 17 cm long, 5 to 13 cm wide, with 5 to 9 deep lobes often terminated by secondary lobes with bristle tips, sinuses usually deep, round, and wider than lobes; both surfaces pale green, upper surface shiny, bright scarlet in autumn, petioles about 4 cm long. **Flowers** unisexual; staminate in catkins with developing leaves; pistillate on pubescent peduncles. **Fruit** an acorn; cup 15 to 30 mm wide, covered with brown scales enclosing about one-third to one half of the nut; nut ovoid, 10 to 20 mm long, occasionally with ring grooves near apical point at maturity.



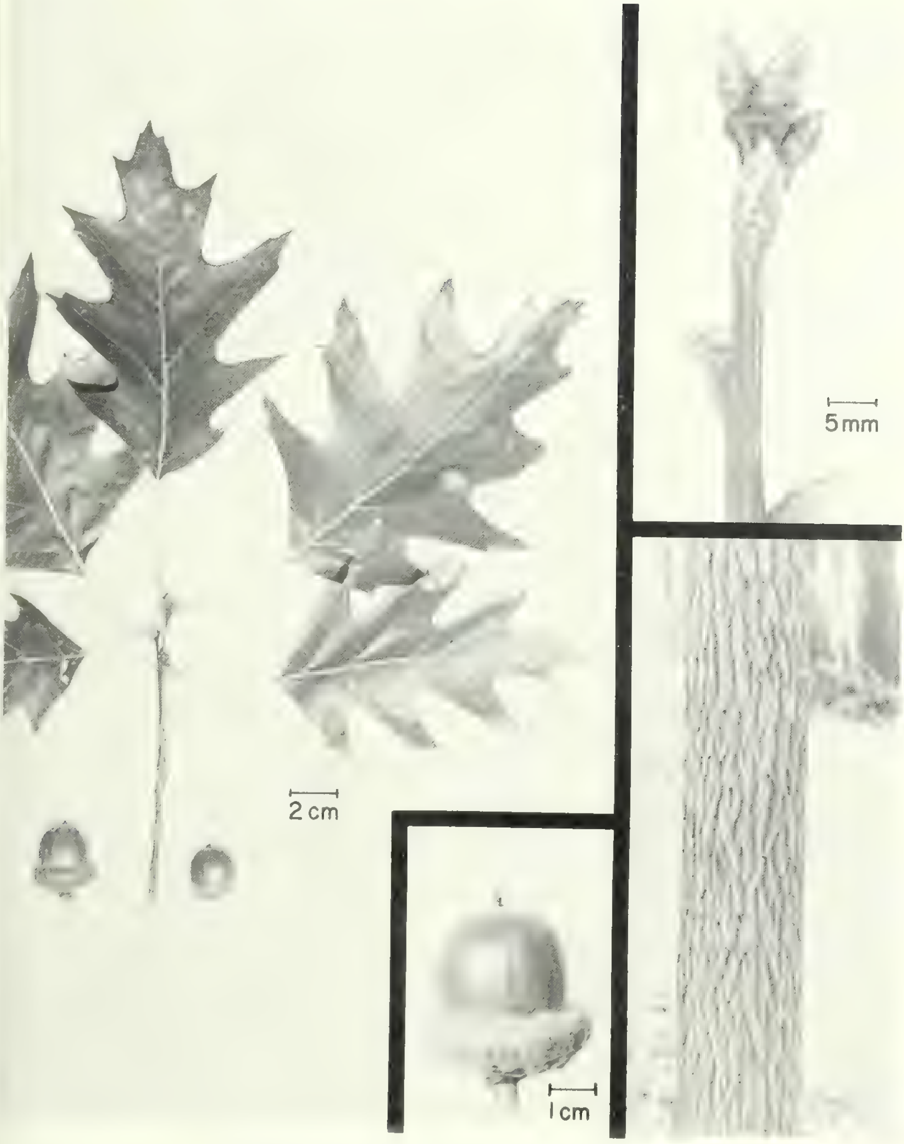
Scarlet Oak/*Quercus coccinea*

Northern Red Oak

Quercus rubra L.



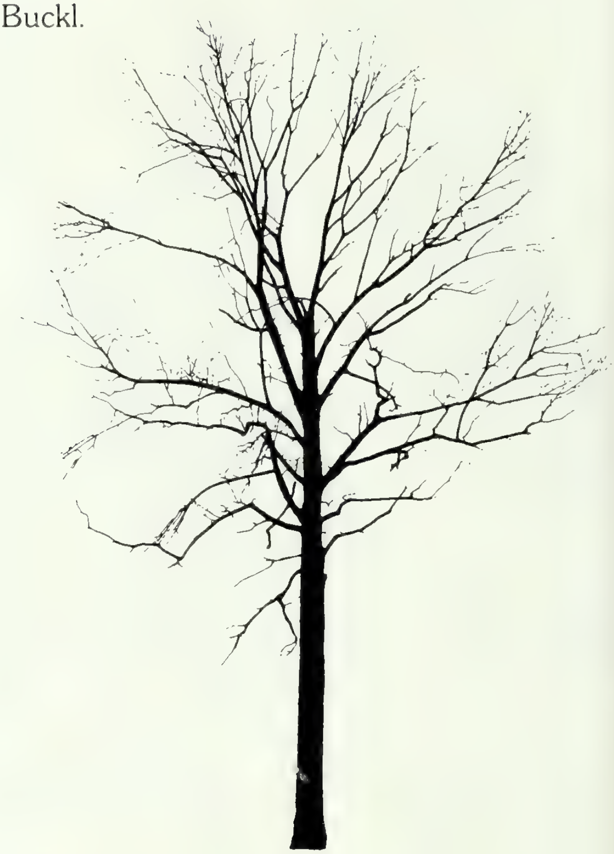
Bark dark brown, thick, divided by shallow furrows into long, flat-topped scaly ridges **Branches** stout, spreading and ascending to form a round topped crown. **Twigs** slender, reddish brown to dark red. **Buds** ovate, acute, light brown, 8 to 10 mm long. **Leaves** alternate, deciduous, simple, oblong to oval to obovate, 12 to 22 cm long, 10 to 15 cm wide, 7 to 11 short lobes, lobes 3 toothed, bristle-tipped, upper surface dull green. **Flowers** unisexual, staminate in slender catkins appearing with the developing leaves, pistillate inconspicuous on last year's wood. **Fruit** an acorn, 15 to 30 mm long; cup saucer-shaped, enclosing about one-fourth of the nut.



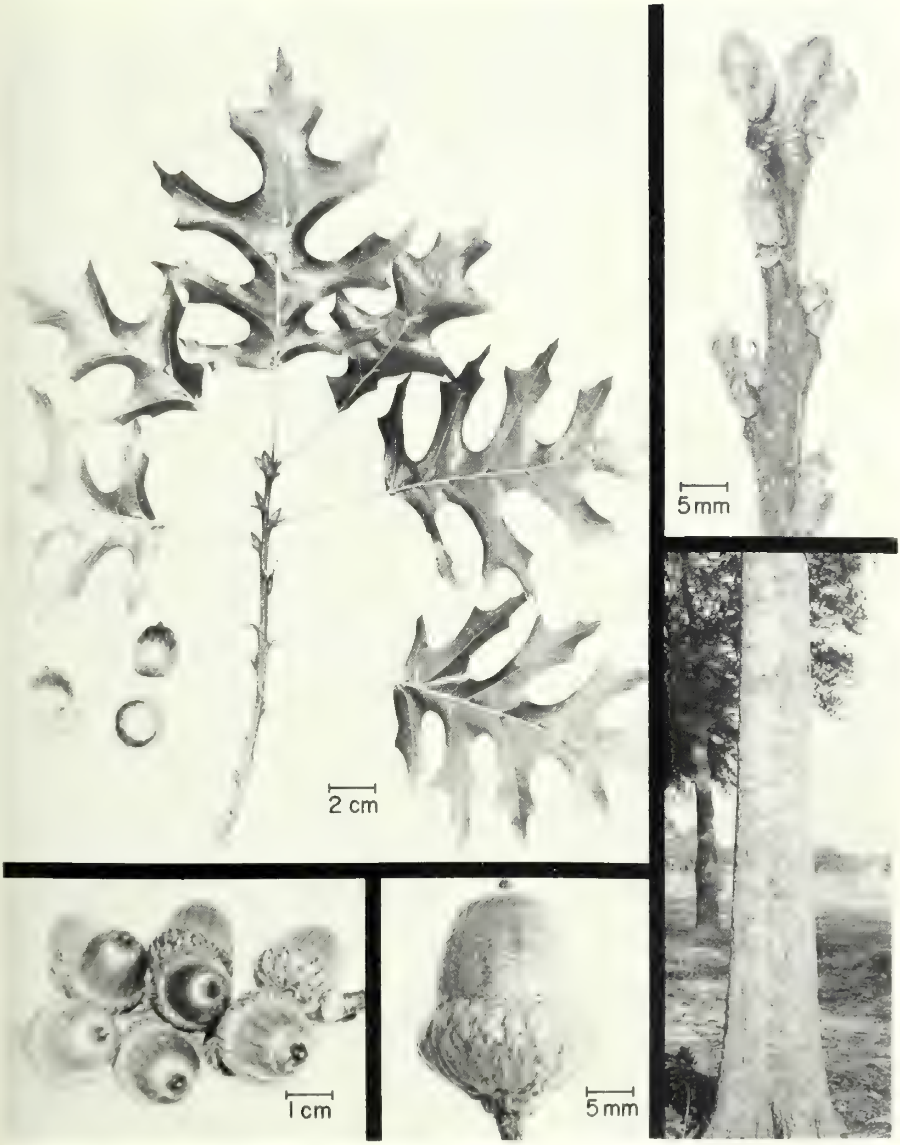
Northern Red Oak/*Quercus rubra*

Shumard Oak

Quercus shumardii Buckl.



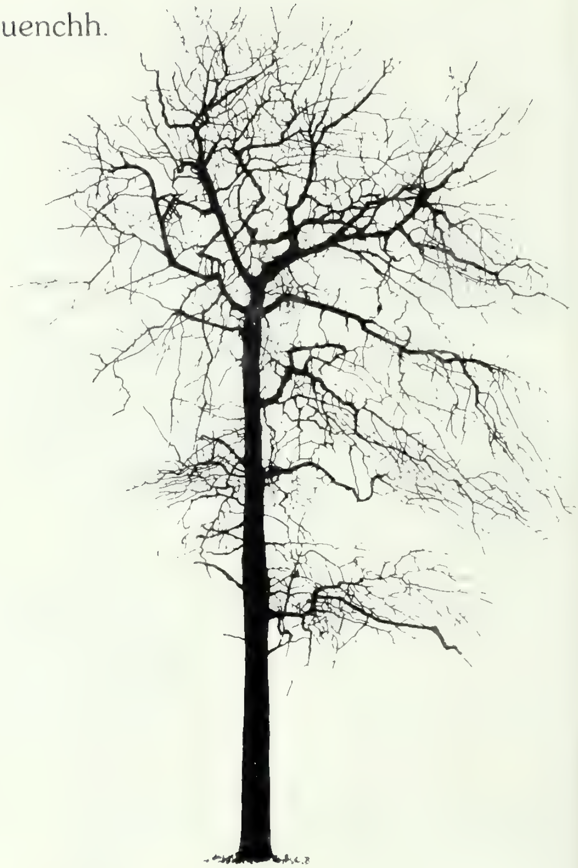
Bark dark gray to blackish, relatively smooth at first, then breaking into scaly ridge **Branches** spreading to ascending. **Twigs** about 5 mm in diameter, olive green the turning dark reddish. **Buds** clustered at apex, 5 to 7 mm long, sharp pointed, strongl angled. **Leaves** alternate, deciduous, simple; oval to slightly obovate, 10 to 20 cm long, to 15 cm wide; with 7 to 10 bristle-tipped lobes, lobes on upper crown leaves narrower t slightly wider than sinuses, lobes on lower crown leaves wider than sinuses; dark gree above, paler below, glabrous except for vein axils on lower surface; petiole about 5 cr long. **Flowers** unisexual; staminate in yellow catkins appearing with the unfolding leave pistillate on pubescent peduncles. **Fruit** an acorn; cup 20 to 31 mm across, enclosir about one-fourth of the nut; nut about 25 mm long, 15 mm in diameter.



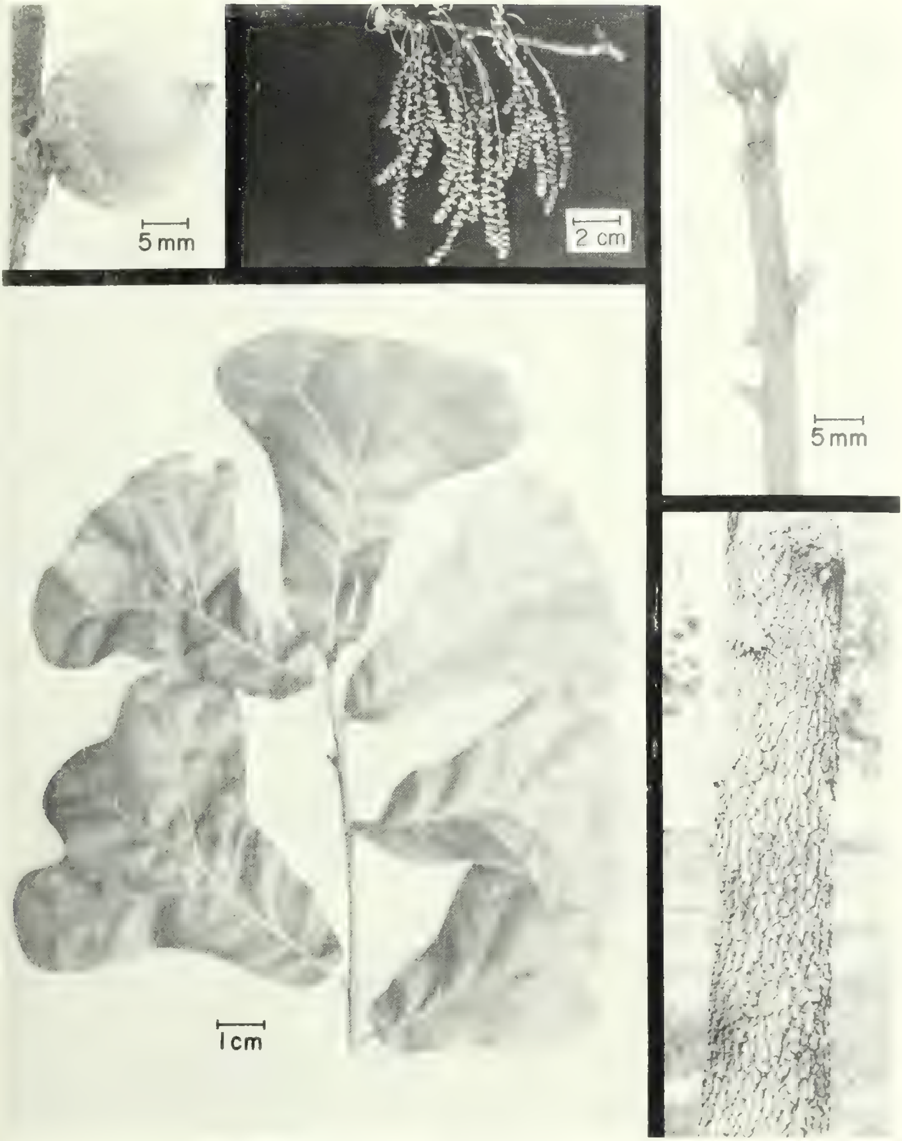
Shumard Oak/*Quercus shumardii*

Blackjack Oak

Quercus marilandica Muenchh.



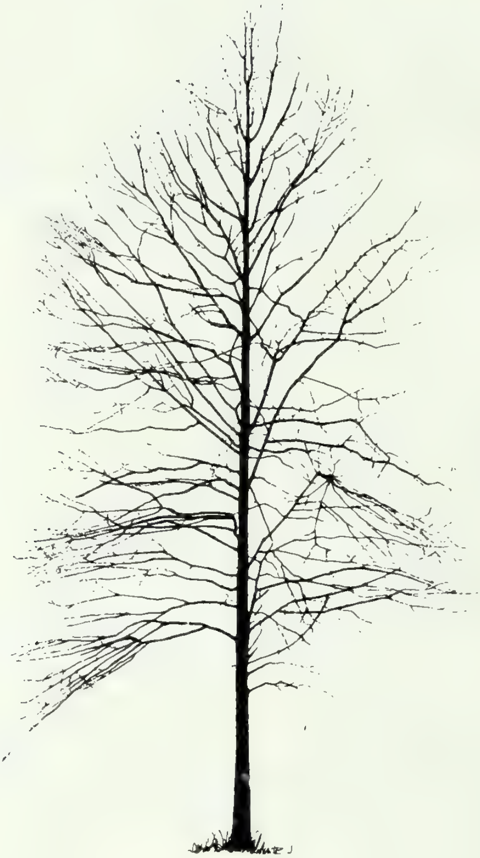
Bark black, very rough, consisting of thick blocky plates. **Branches** stout, spreading to drooping. **Twigs** stout, about 5 mm in diameter. **Buds** with rusty brown hairs, about 4 to 8 mm long. **Leaves** alternate, tardily deciduous, simple, 7 to 25 cm long, broadly obovate at apex (bear-paw shape) tapering to a narrow base, margin entire or with 3 bristle-tipped apical lobes, upper surface dark green, rusty pubescent on undersurfaces. **Flowers** unisexual; staminate in catkins, appearing with the leaves, pistillate solitary or paired. **Fruit** an acorn, cup enclosing one-half to two-thirds of the nut; nut nearly ovoid, 20 to 25 mm long by 15 to 20 mm in diameter.



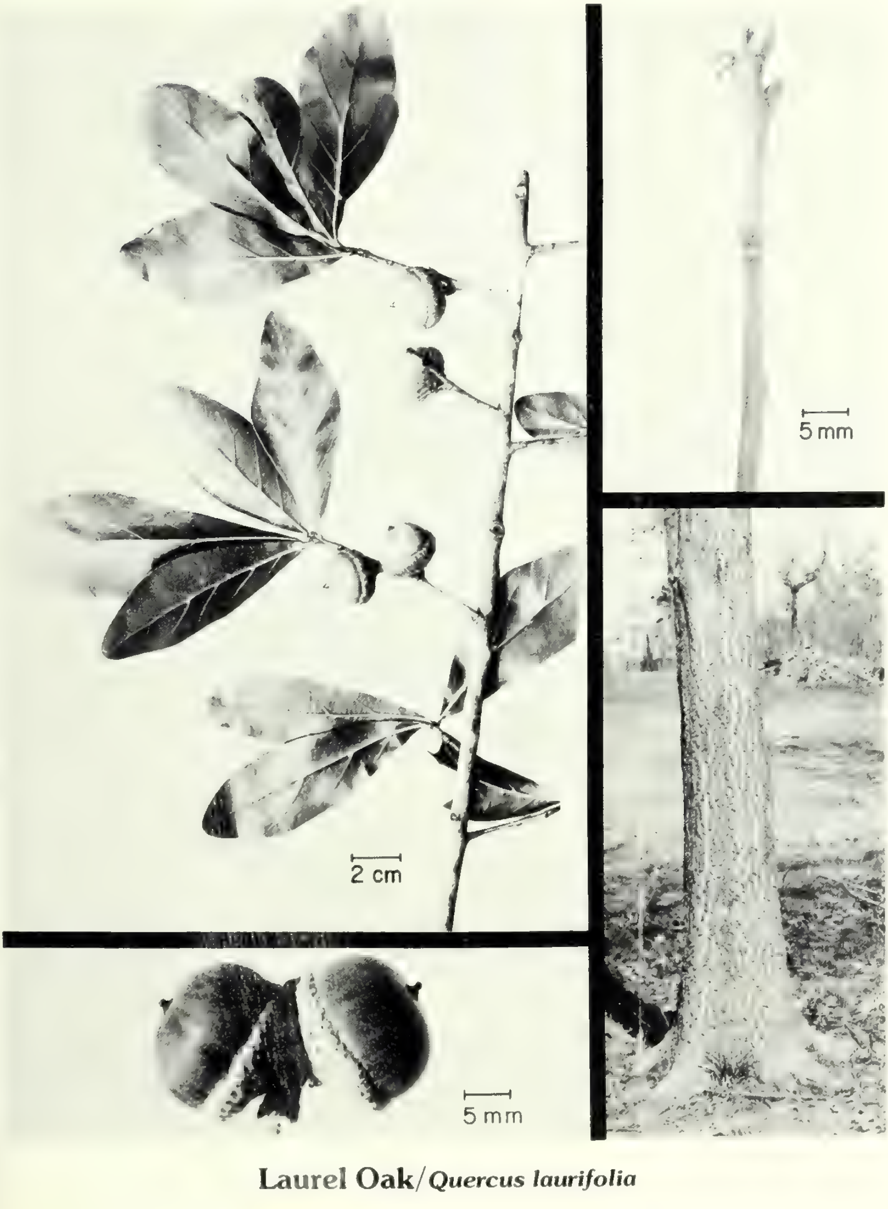
Blackjack Oak/*Quercus marilandica*

Laurel Oak

Quercus laurifolia Michx.



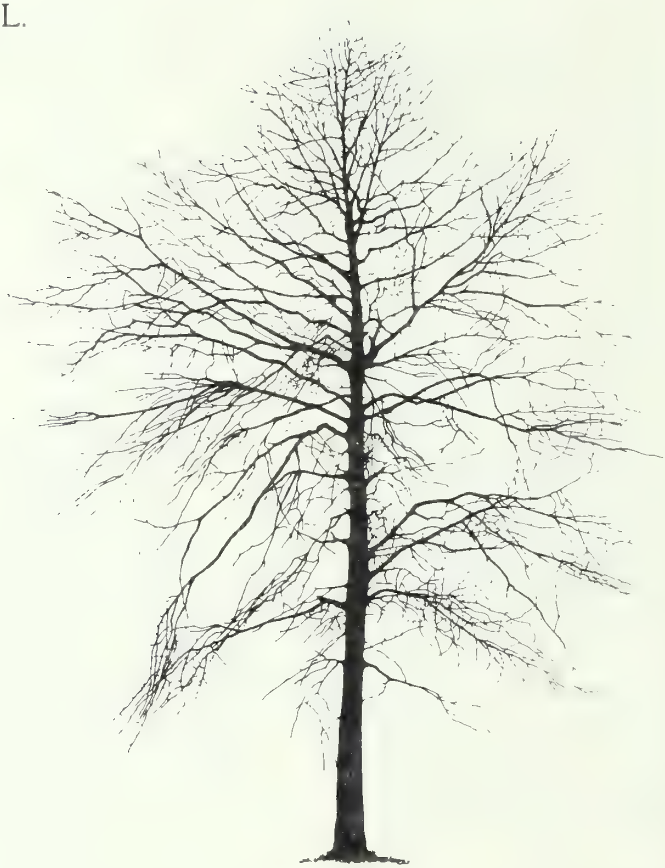
Bark nearly black, divided into broad flat ridges by deep fissures. **Twigs** 2 to 3 mm in diameter, usually reddish brown. **Buds** ovoid, reddish brown, 2 to 4 mm long. **Leaves** alternate, semi-deciduous, simple, a few shed in fall, a few persisting until spring; elliptic to spatulate, 7 to 15 cm long, 2 to 4 cm wide; apex acute or obtuse, margin entire, base cuneate; shiny green above, paler below; petioles 3 to 5 mm long, midrib conspicuous on underside. **Flowers** unisexual; staminate in catkins as leaves unfold; pistillate on twigs at leaf scars. **Fruit** an acorn, sessile to subsessile, cup 15 to 20 mm wide, enclosing about one-fourth of nut; nut hemispheric, rounded at apex and flattened at bottom, 15 mm long.



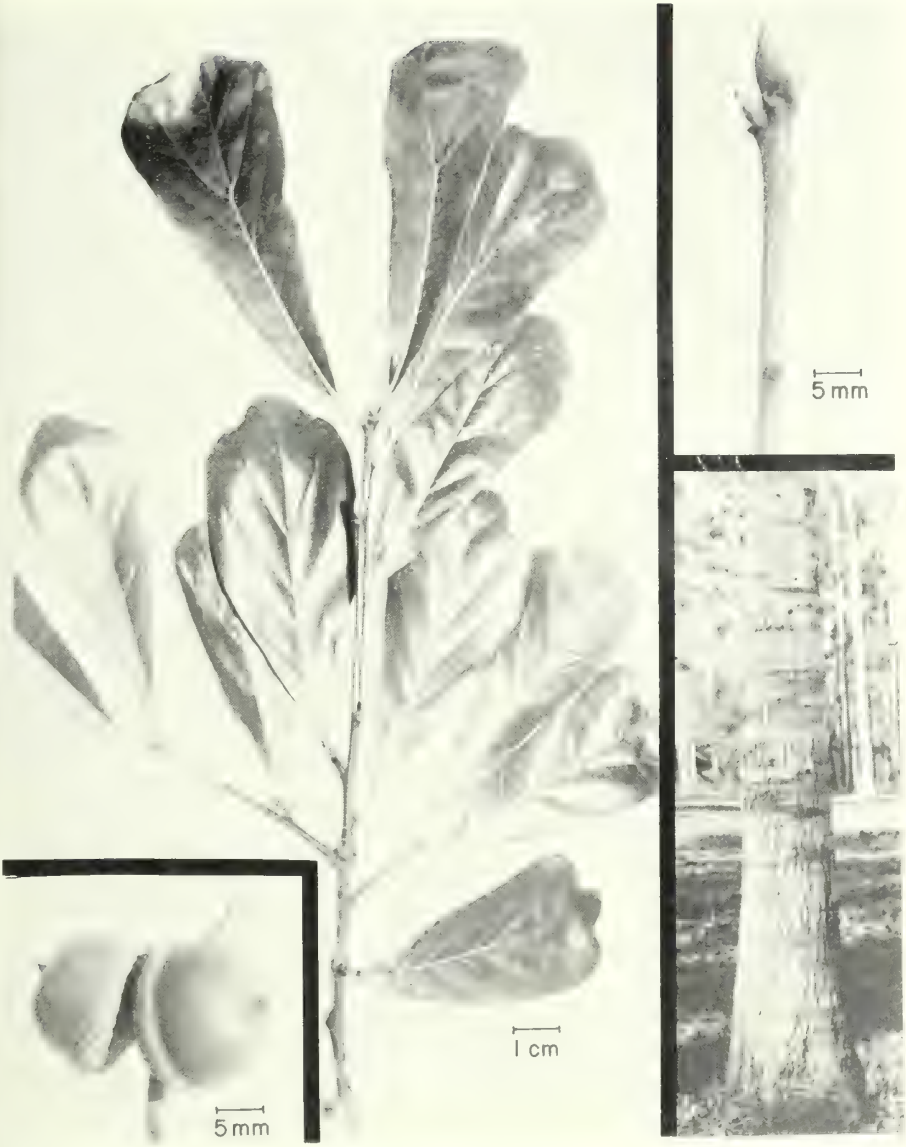
Laurel Oak/***Quercus laurifolia***

Water Oak

Quercus nigra L.

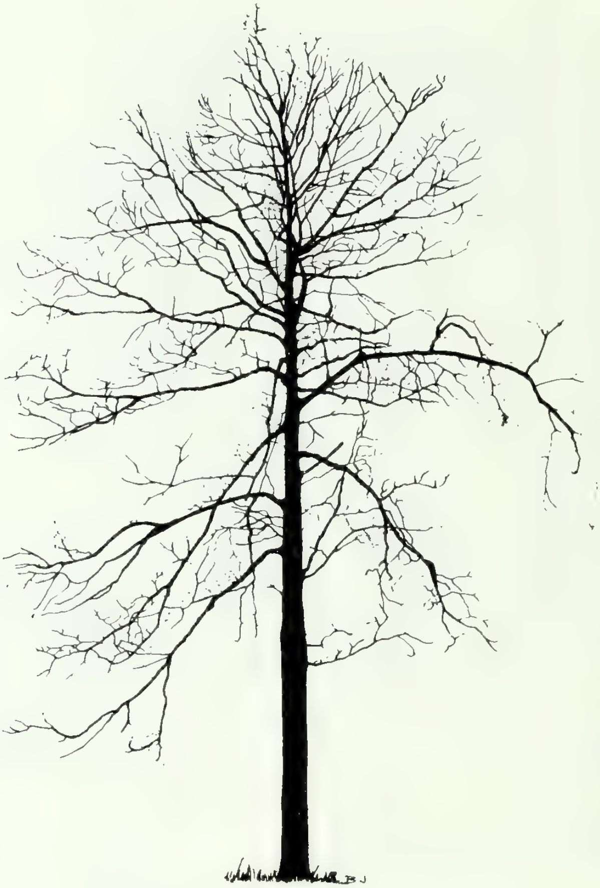


Bark smooth, grayish black, becoming scaly with age. **Branches** spreading to ascending, forming a round-topped crown in the open. **Twigs** 3 to 5 mm in diameter, gray. **Buds** ovoid, acute, reddish brown, 3 to 7 mm long. **Leaves** alternate, deciduous, simple; variable in shape and size, obovate to spatulate, 5 to 10 cm long, 2 to 5 cm wide; margin entire, wavy to distinctly lobed in juvenile specimens; sessile or with petiole to 1 cm long. **Flowers** unisexual; staminate catkins 5 to 8 cm long, pistillate catkins short-peduncled. **Fruit** an acorn about 15 mm wide, 10 mm high; cup thin, enclosing about one-fifth to one-third of the nut.

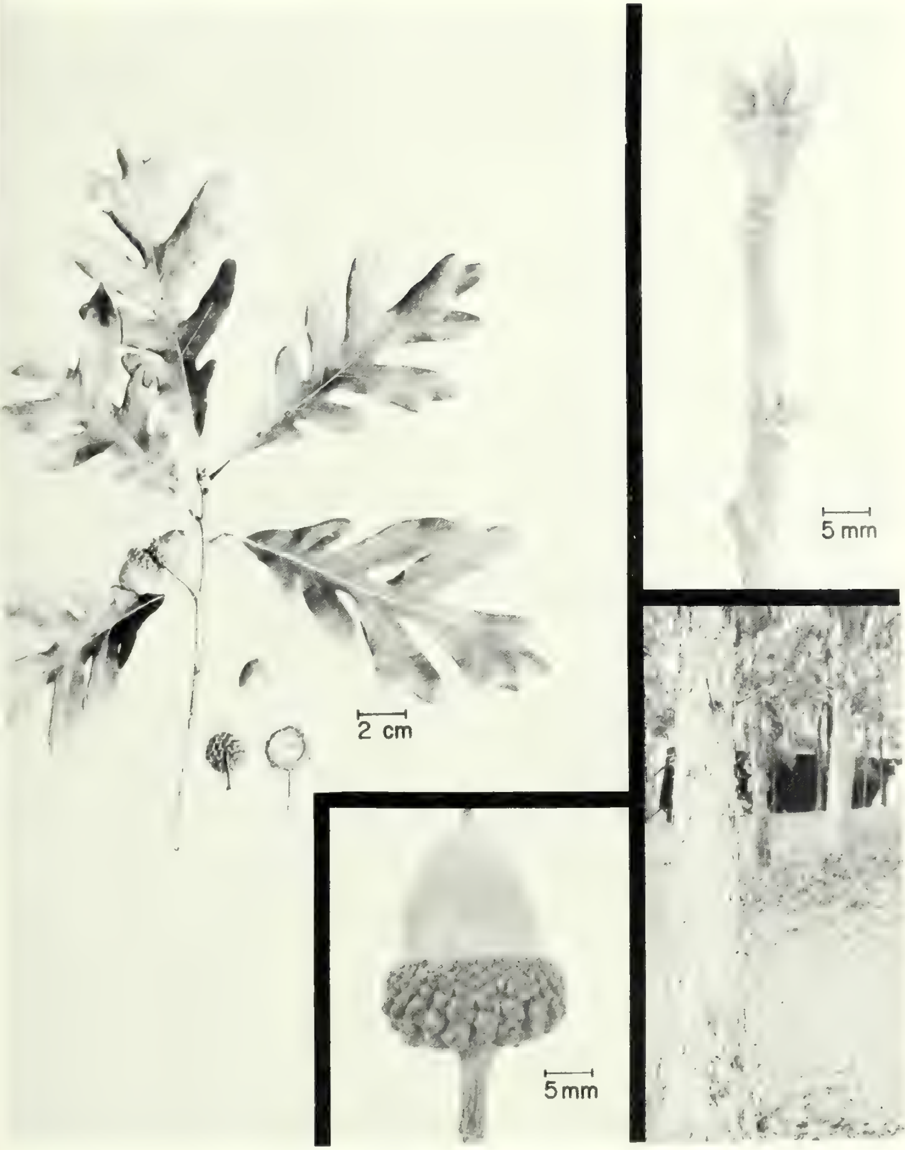


Water Oak/*Quercus nigra*

White Oak
Quercus alba L.



Bark light gray, separated by shallow furrows into flat ridges with loose appressed scales. **Branches** stout, drooping, spreading to ascending. **Twigs** 2 to 3 mm in diameter, reddish. **Buds** globose to ovoid, angulate, apex acute to obtuse, 3 to 5 mm. **Leaves** alternate, deciduous, simple, oblong to obovate, 7 to 20 cm long, 4 to 10 cm wide, with 7 to 11 uneven, rounded lobes and deep sinuses. **Flowers** unisexual, in catkins, preceding leaf expansion. **Fruit** an acorn, 15 to 35 mm long, 20 to 25 mm in diameter, cup 1.5 to 3 cm wide, usually cup-shaped, conspicuous with thickened scales, enclosing one-fourth to one-third of the nut.

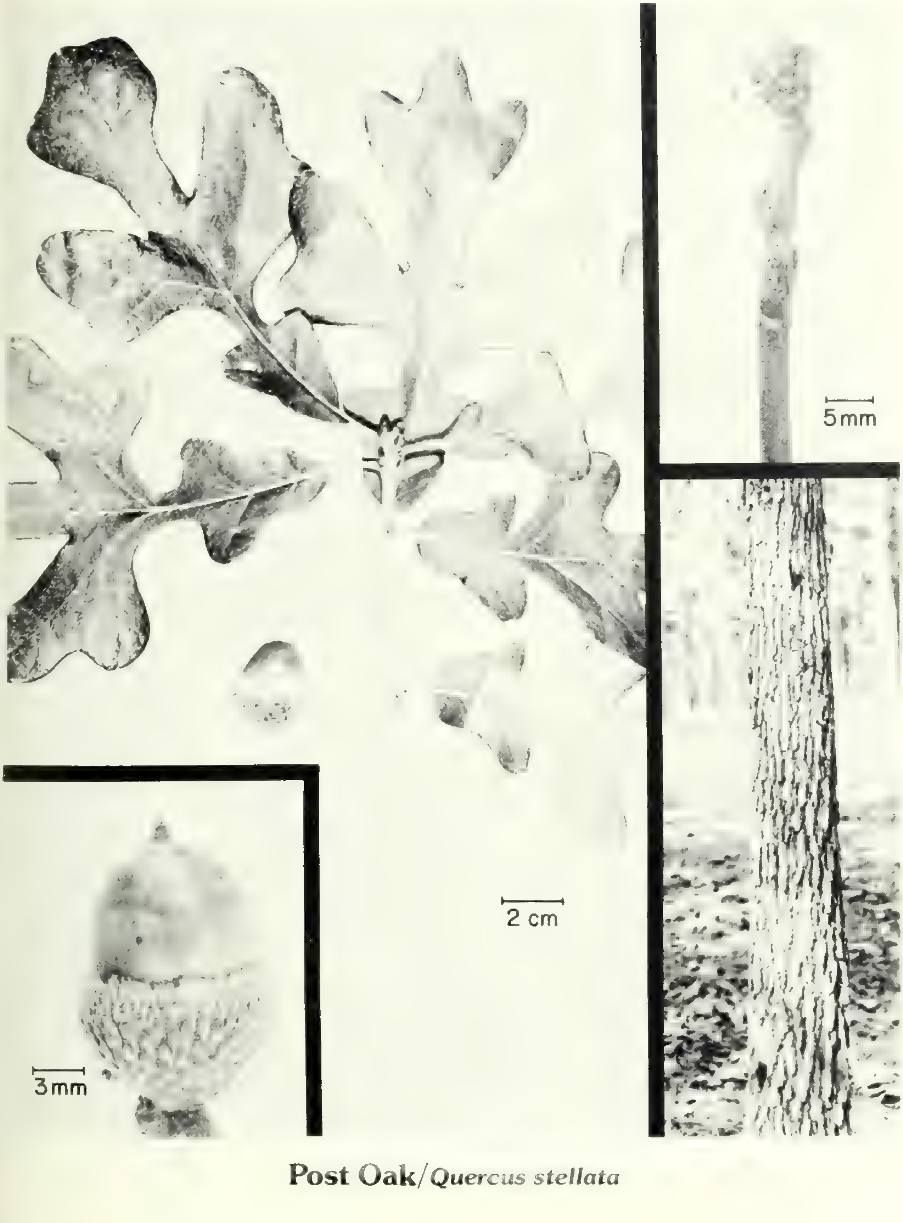


White Oak/*Quercus alba*

Post Oak

Quercus stellata Wangenh.

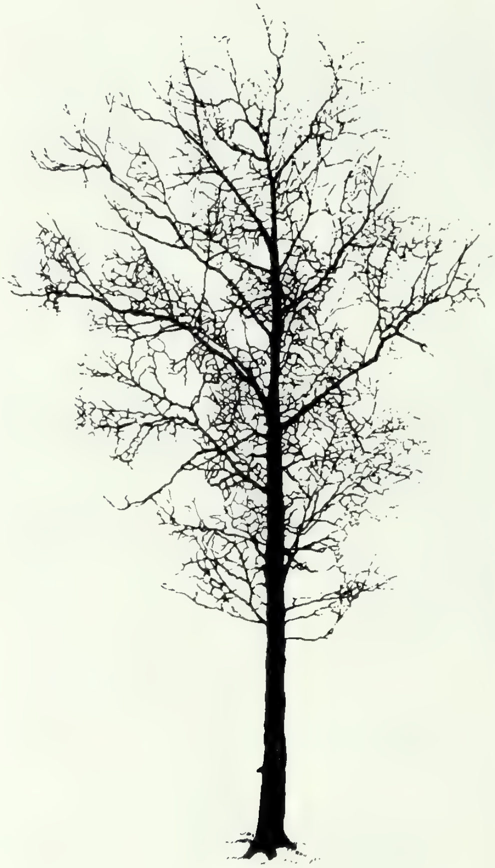
Bark medium to dark gray, with deep furrows, scaly ridges. **Branches** stout, irregular, drooping to horizontal and ascending. **Twigs** 3 to 5 mm in diameter, gray to brownish. **Buds** broadly ovate, blunt to acute, 5 mm long, clustered at apex of twig. **Leaves** alternate, deciduous, simple; obovate, to 18 cm long, 5 to 10 cm wide; divided into 5 to 7 sinuate rounded lobes, the two lower lobes smaller than the upper pair, upper lobes and the terminal lobe resembling a cross, dark, shiny green above, grayish to brownish below, leathery. **Flowers** unisexual, staminate in catkins appearing with the unfolding leaves; pistillate on last year's wood. **Fruit** an acorn, 13 to 25 mm long, 6 to 20 mm in diameter; cup hemispherical, enclosing about one-half of the nut, cup scales rusty-pubescent; nut ovate to ovate-oblong, about 15 mm long.



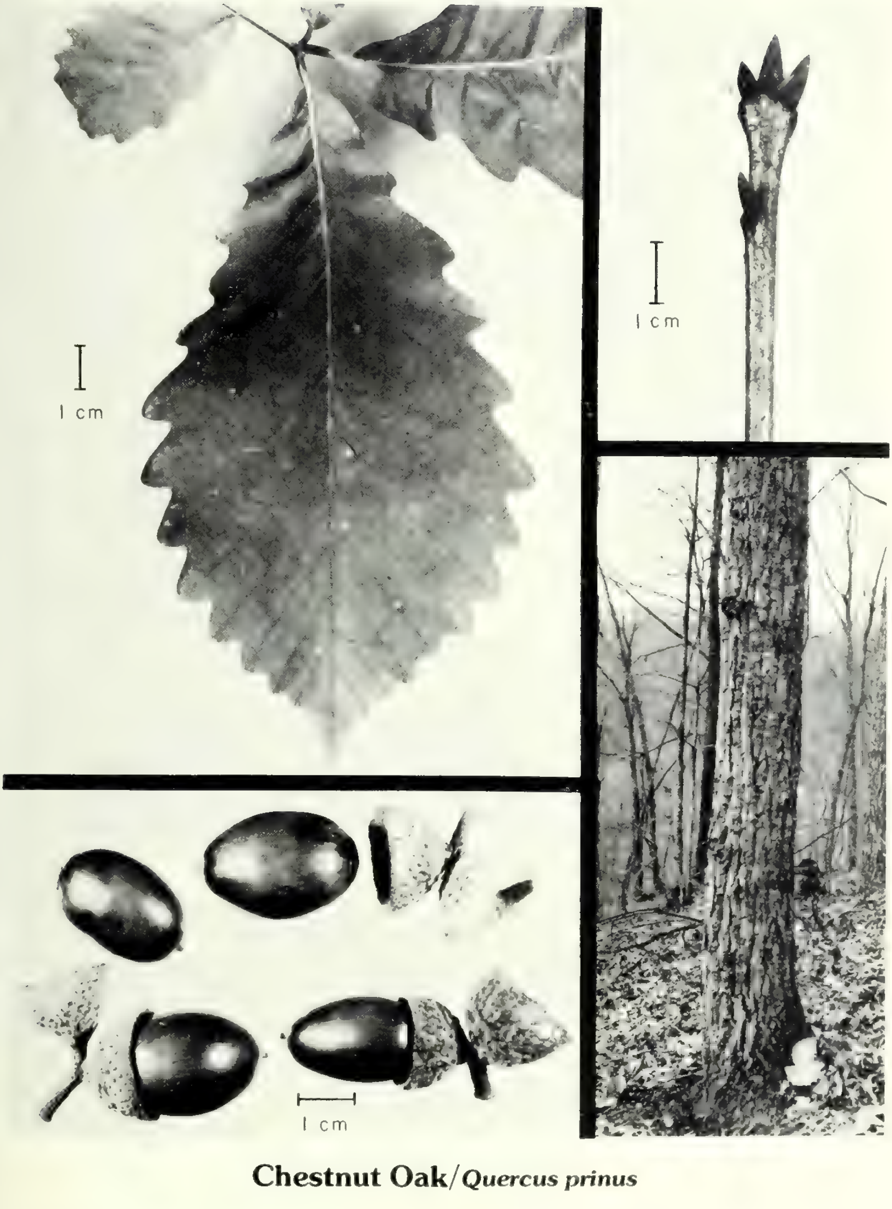
Post Oak/*Quercus stellata*

Chestnut Oak

Quercus prinus L.



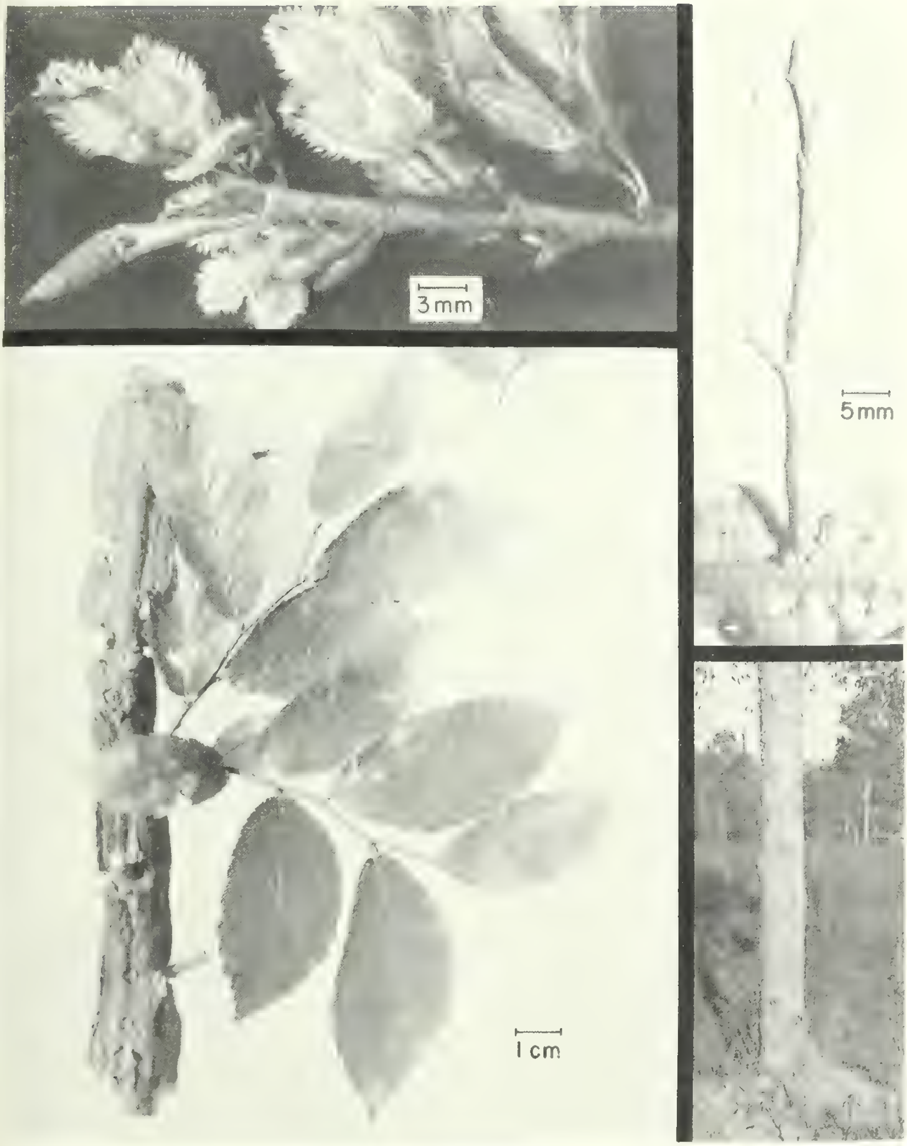
Bark dark reddish brown to nearly black, deeply furrowed with narrow ridges. **Branches** stout, spreading to ascending. **Twigs** stout, angulate, smooth, purplish-green when new, turning orange or reddish-brown. **Buds** ovate-conical somewhat angulate, 8 to 12 mm long, silky hairy. **Leaves** alternate, deciduous, simple; elliptic to obovate, 10 to 30 cm long, 3 to 8 cm wide; somewhat leathery, margin crenate with a vein ending in each rounded tooth, smooth green above, stellate-pubescent below. **Flowers** unisexual; staminate in catkins 5 to 10 cm long; pistillate in short spikes on stout peduncles. **Fruit** an acorn 25 to 35 mm long, 15 to 25 mm in diameter; cup vase-shaped, thin, rough with thickened scales, covering one-third to one-half of the nut.



Chestnut Oak/*Quercus prinus*

Winged Elm
Ulmus alata Michx.

Bark dark, smooth at first becoming deeply furowed on larger trees. **Branches** slender, ascending to spreading, corky ridges or wings on branches 3 years or older. **Twigs** about 2 mm in diameter, light green tinged with red. **Buds** sharp-pointed, divergent from twig 3 to 4 mm long. **Leaves** alternate, deciduous, simple, broadly ovate to elliptic, 4 to 8 cm long, 2 to 4 cm wide; apex acute to short-acuminate, margin doubly to triply serrate, base rounded; dull green above, lighter green below with prominent pinnate veins.**Flowers** perfect, abundant, tiny, opening just before leaves unfold, several in a cluster at a leaf scar, blooming late January into February. **Fruit** a samara, flat and elliptic, 6 to 8 mm long, margin ciliate.

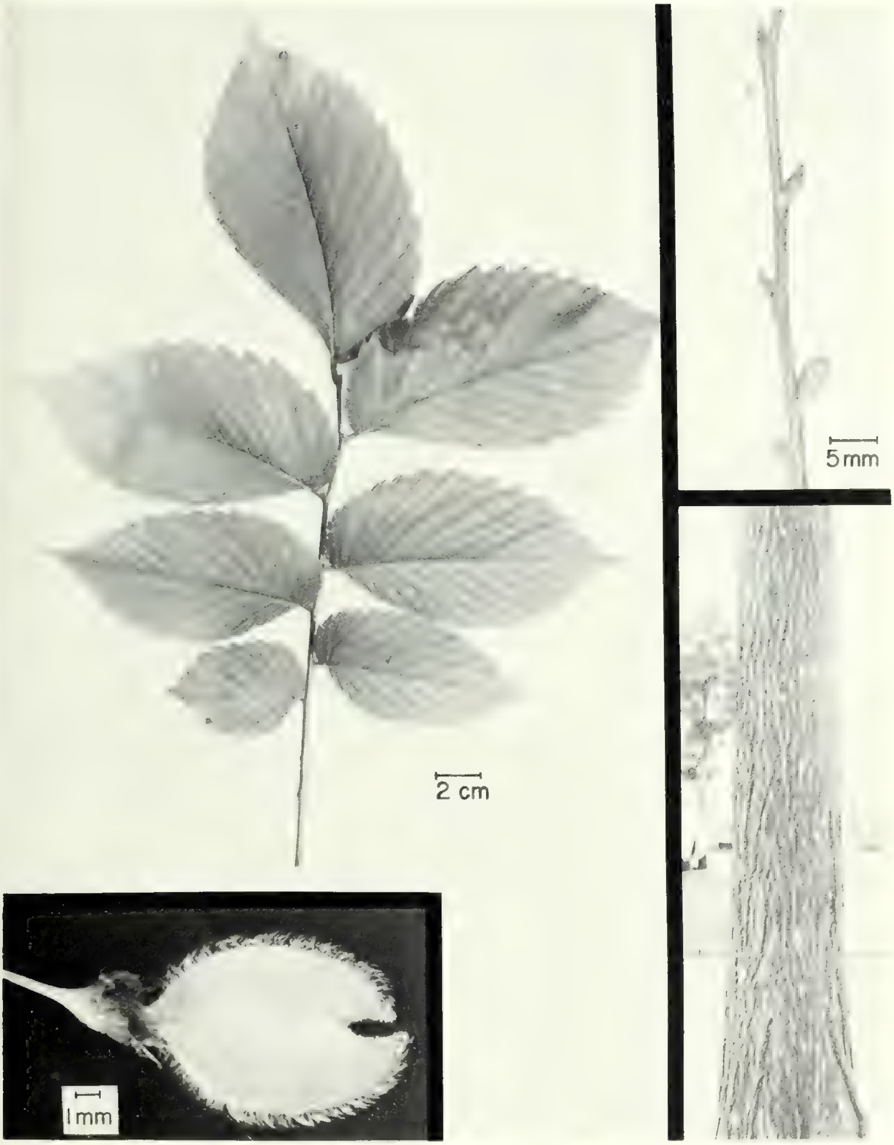


Winged Elm/***Ulmus alata***

American Elm

Ulmus americana L.

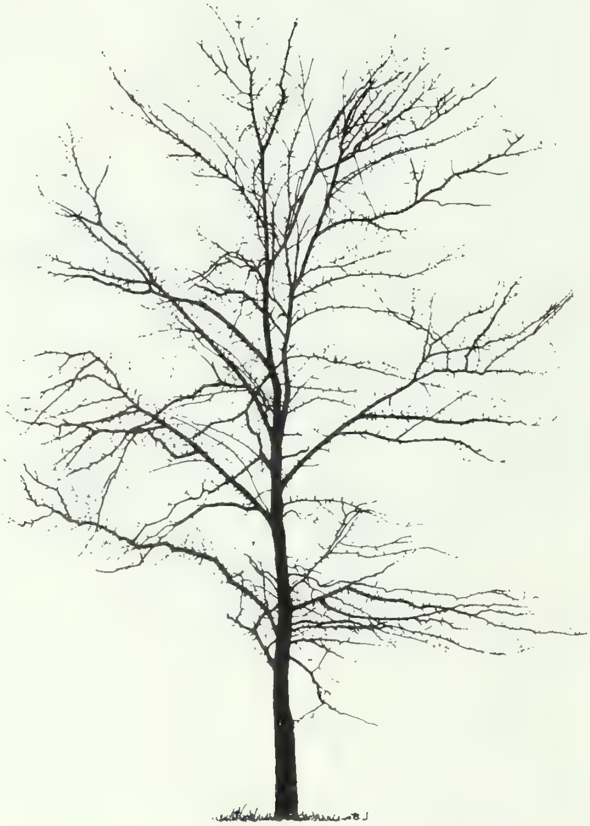
Bark gray to blackish, thick, divided into flat ridges by deep furrows. **Branches** ascending, arching, and spreading; open-grown trees vase-shaped in outline. **Twigs** 2 to 3 mm in diameter with 5 to 7 leaves which increase in size from basal to apical leaf, red-brown. **Buds** (leaf) brown, small, scaly, acute. **Leaves** alternate, deciduous, simple; broadly ovate, 5 to 15 cm long, 4 to 6 cm wide; apex acuminate, margin usually doubly serrate, base oblique on short petiole; upper surface smooth, marked with sunken veins pinnately arranged; veins more prominent on underside. **Flowers** perfect, buds greatly enlarge before opening; with very small flowers abundant in clusters; opening before the leaves expand, blooming from late December into February. **Fruit** a samara, oval to circular with wing surrounding the seed, about 10 mm in diameter, margin ciliate.



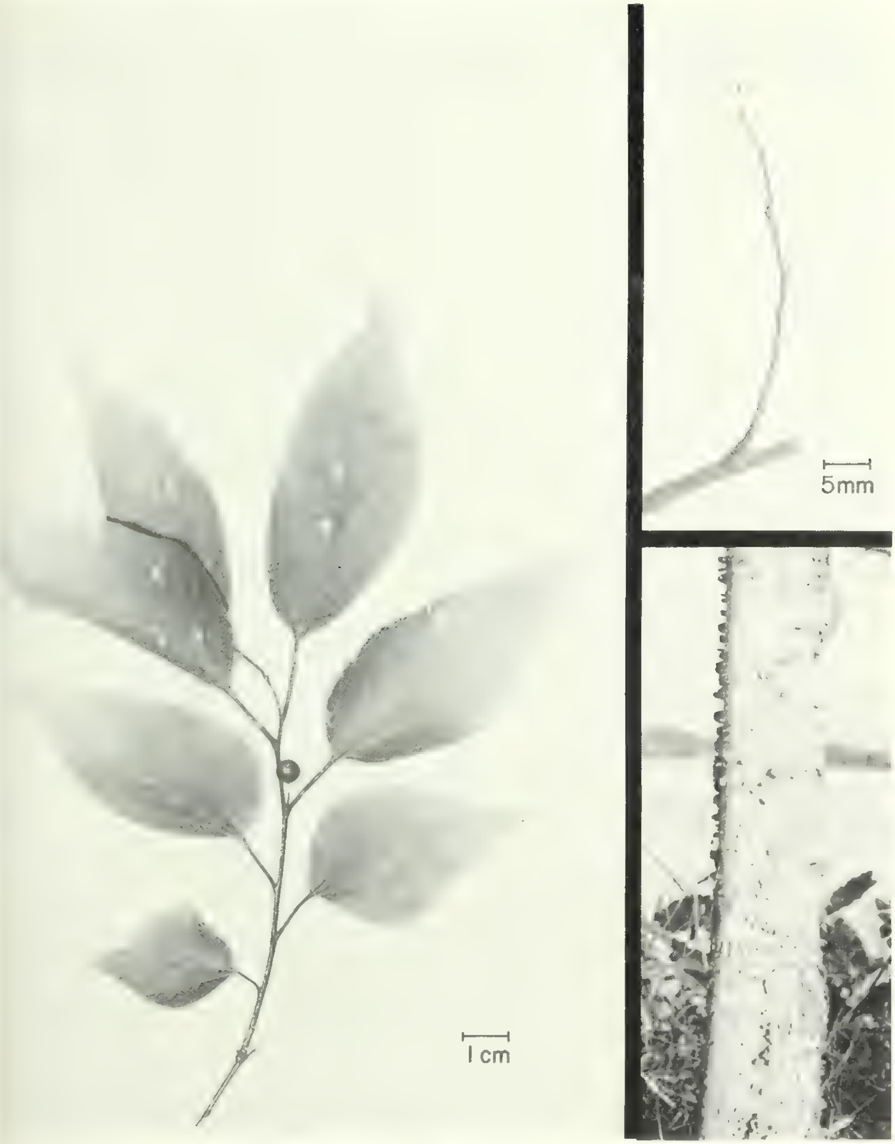
American Elm/***Ulmus americana***

Sugarberry; hackberry

Celtis laevigata Willd.



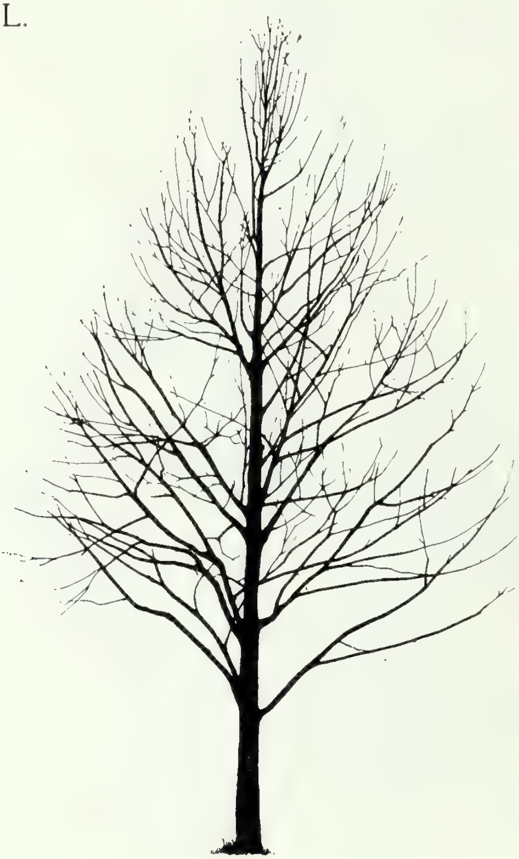
Bark light gray to almost white, thin, smooth, usually more or less studded with irregular corky outgrowths. **Branches** spreading, slender. **Twigs** about 3 mm in diameter, reddish-brown. **Buds** about 3 mm long, alternate. **Leaves** alternate, deciduous, simple, narrowly elliptic to broadly ovate, 6 to 10 cm long, 2 to 4 cm wide; apex acute, margin usually entire, base broadly rounded or oblique. **Flowers** unisexual or perfect, tiny, inconspicuous, many staminate and few pistillate appearing on the new growth as the leaves unfold. **Fruit** a drupe with a bony reticulated nutlet, about 5 mm in diameter, orange-red on a pedicel often shorter than the petiole of the subtending leaf.



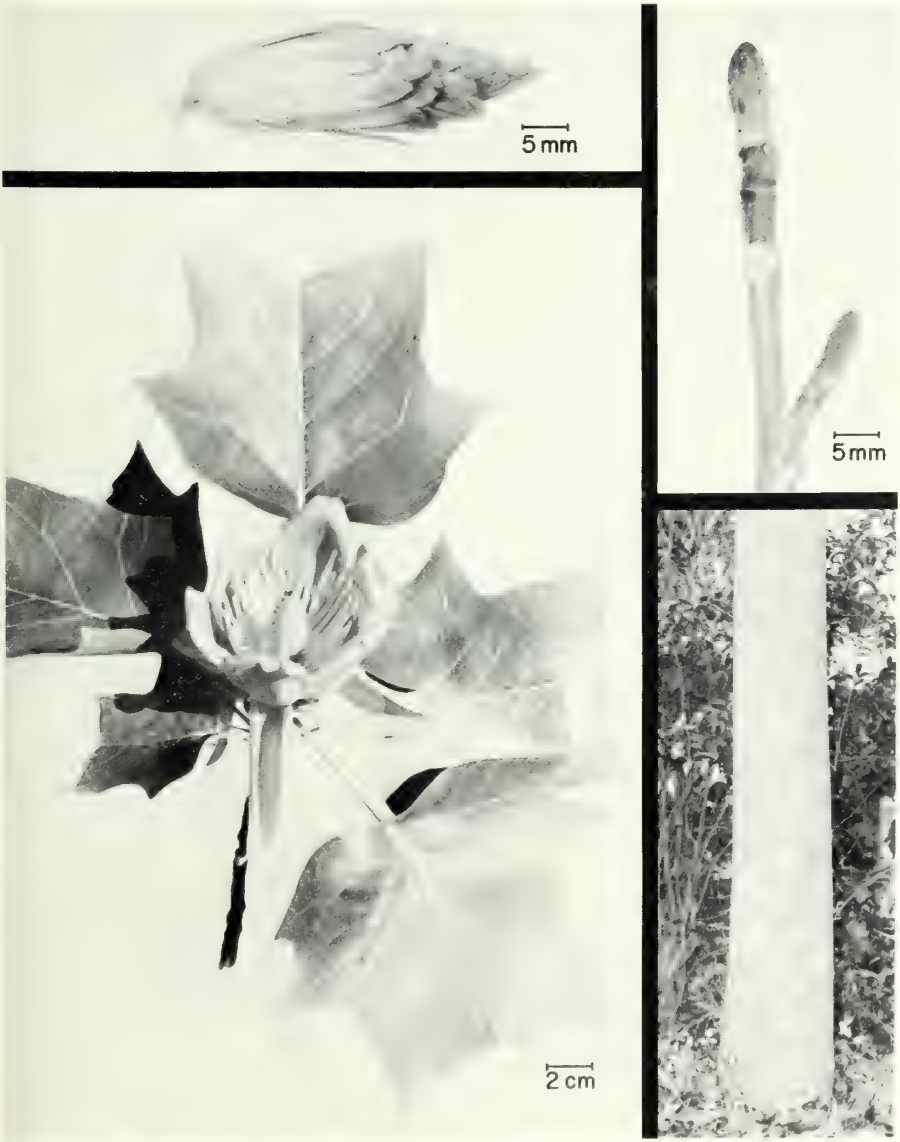
Sugarberry; hackberry/*Celtis laevigata*

Yellow-poplar

Liriodendron tulipifera L.



Bark thin and dark green on young trees, becoming ash-gray and conspicuously furrowed and ridged with age. **Branches** spreading to ascending, often drooping on large open-grown trees. **Twigs** smooth, about 5 mm in diameter, encircled by stipule scars, red-brown. **Buds** (terminal) grayish green, turning red in winter, flat about 10 to 16 mm long, scales valvate. **Leaves** alternate, deciduous, simple; dark green above, turning yellow in fall; 6 to 20 cm long and as wide as long; petioles 5 to 20 cm long, often longer than the blades on low branches. **Flowers** perfect, tulip-shaped, about 4 to 6 cm long, greenish-yellow with orange to reddish markings at base of petals, color intensifies with age. **Fruit** an aggregate cone, 5 to 8 cm long, gradually shattering into one-seeded, winged samaras.

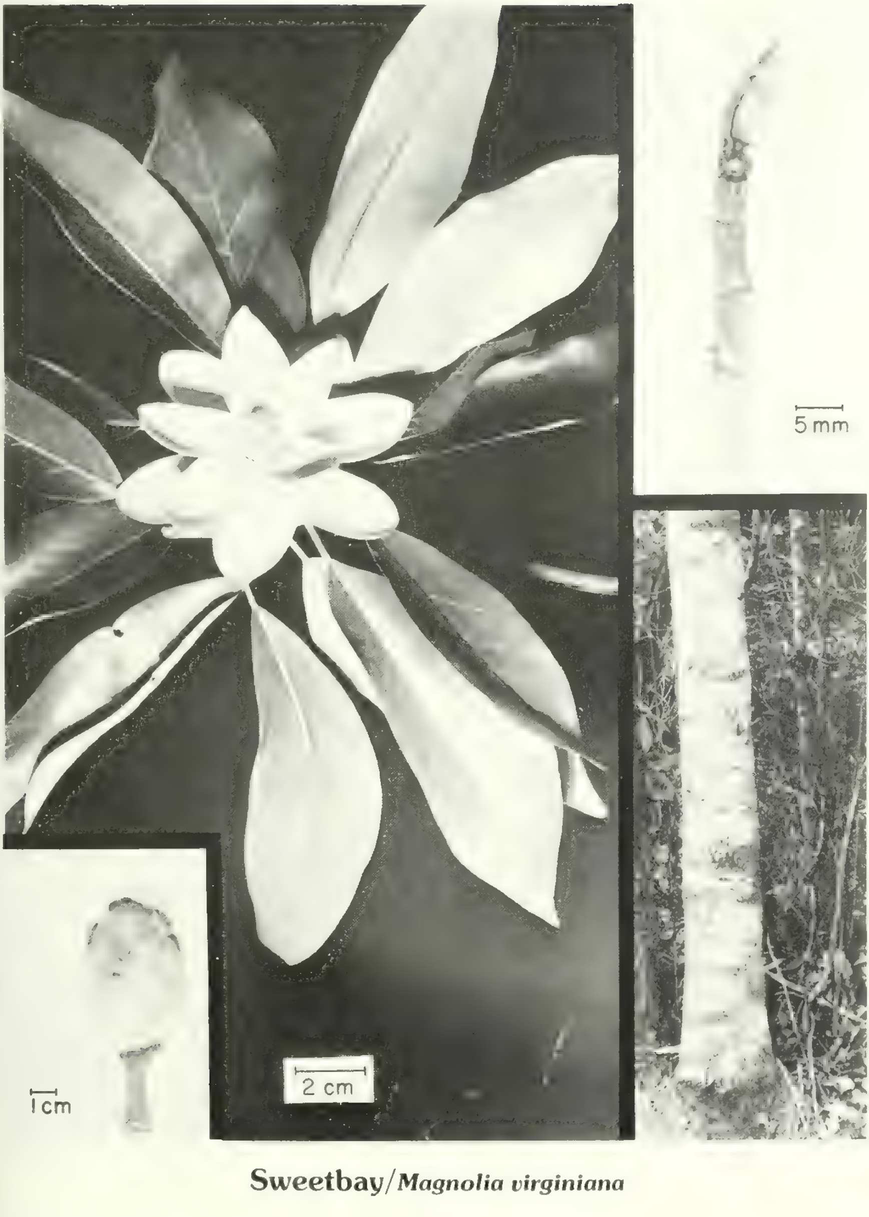


Yellow-poplar/*Liriodendron tulipifera*

Sweetbay

Magnolia virginiana L.

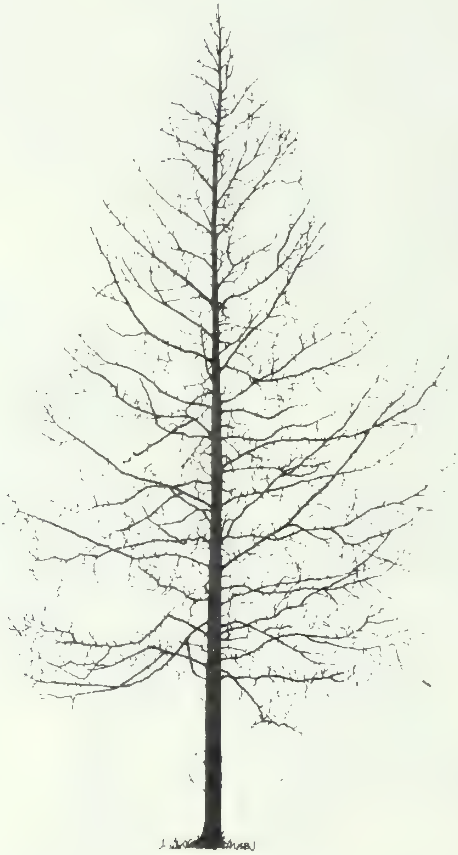
Bark dark gray, usually smooth, thin, in shady areas often encrusted with mosses, liverworts, and lichens. **Branches** stout, spreading to ascending. **Twigs** about 5 to 7 mm in diameter, encircled by stipule scars, green. **Buds** (terminal), silvery gray, pubescent, 15 mm long; smaller lateral buds often subtended by persistent petiole base. **Leaves** alternate, evergreen in South, deciduous in northern part of range, simple; elliptic to oblong, 10 to 15 cm long, 4 to 6 cm wide; margin entire, dark green above, silvery pubescent below. **Flowers** perfect, white, sweet-scented, 5 to 8 cm in diameter, appearing May to September. **Fruit** an aggregate of follicles which open and shed red seeds, irregular in shape, ovoid to ellipsoid, smooth, about 5 cm long.



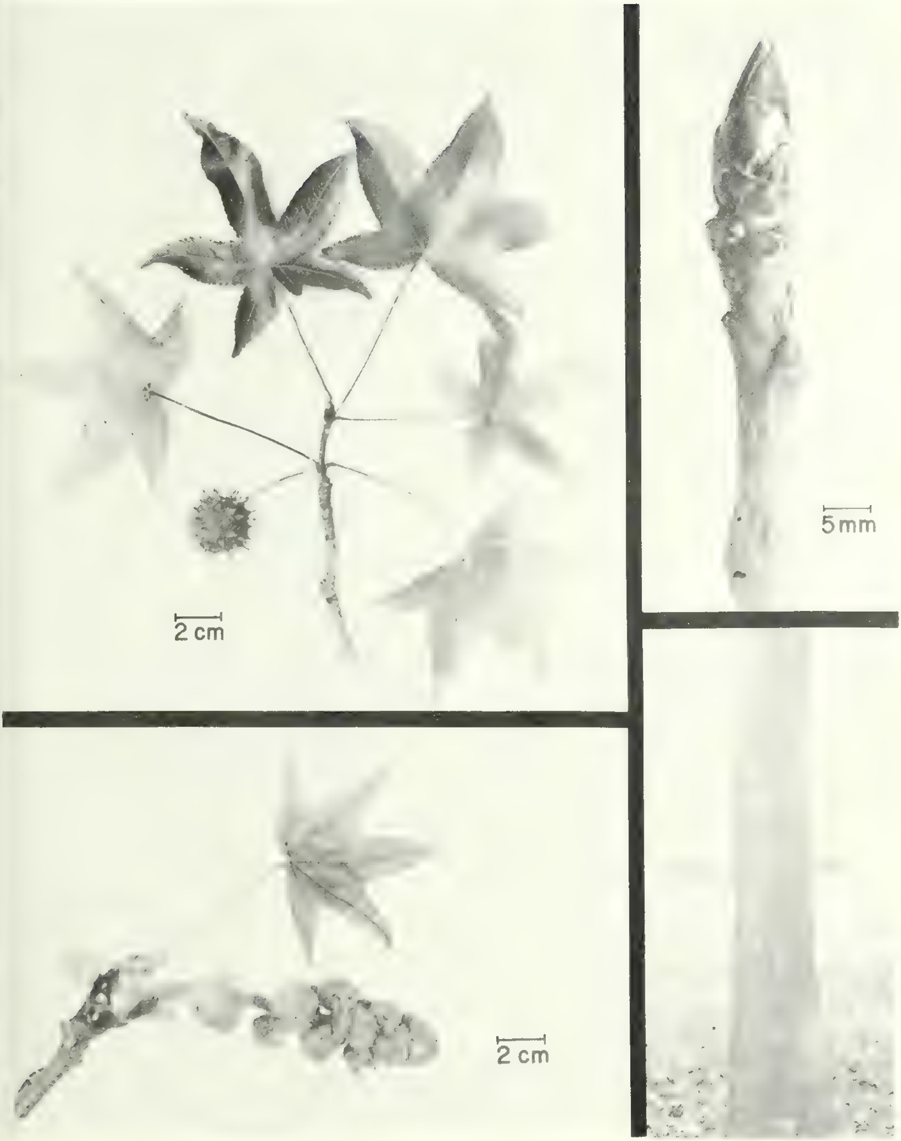
Sweetbay/***Magnolia virginiana***

Sweetgum; redgum

Liquidambar styraciflua L.

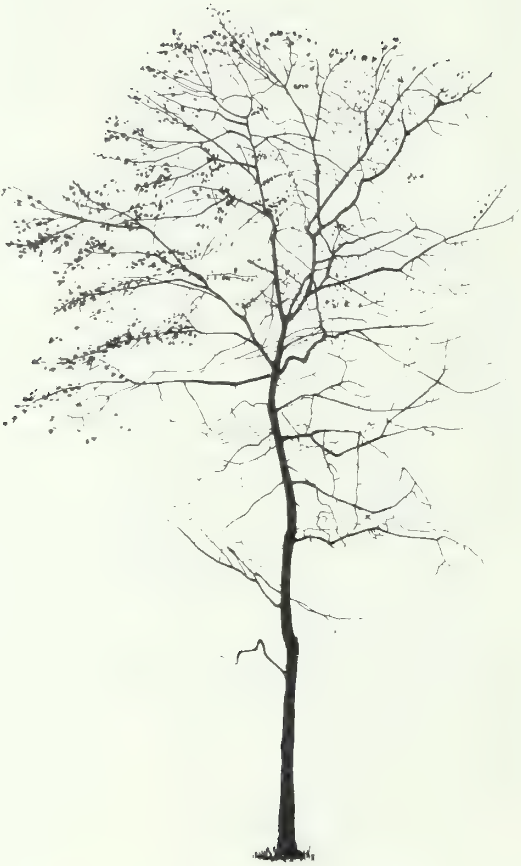


Bark dark gray, divided by deep furrows into narrow, rounded ridges. **Branches** stout, often with corky wings or outgrowths. **Twigs** about 4 to 6 mm in diameter, gray-brown. **Buds** (terminal) broadly egg-shaped, about 10 to 15 mm long, scales overlapping, slightly sticky. **Leaves** alternate, deciduous, simple; palmately 5- to 7-lobed; 8 to 20 cm wide, 6 to 15 cm long, often longer than broad; margin finely serrate; petioles 4 to 13 cm long. **Flowers** unisexual (plants monoecious), appearing as the leaves unfold; staminate clustered in terminal racemes, pistillate in small drooping spherical heads. **Fruit** in stalked spherical heads covered with small spine-like projections, seed cavity at base of each spine



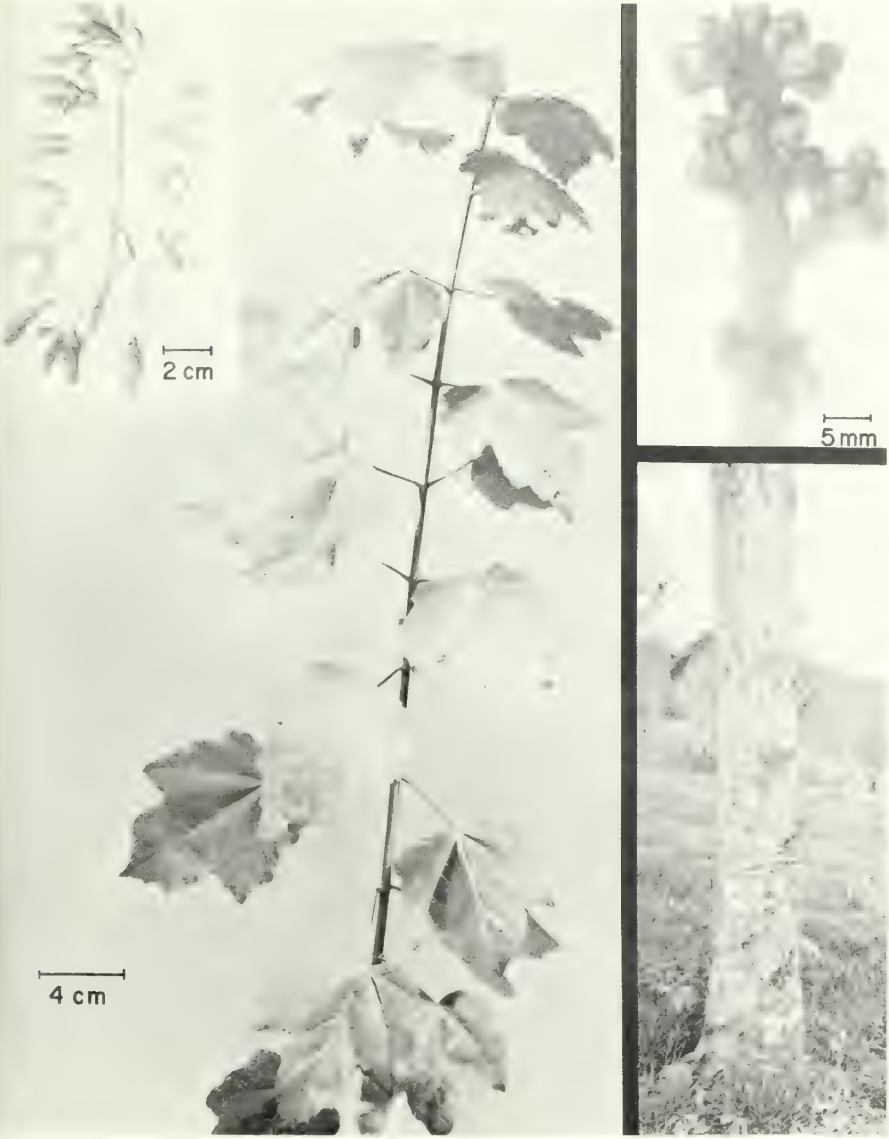
Sweetgum; redgum/***Liquidambar styraciflua***

Red Maple
Acer rubrum L.



Bark gray, divided into scaly ridges by narrow furrows. **Branches** slender, spreading and ascending. **Twigs** about 3 mm in diameter, reddish. **Buds** spherical, reddish, clustered at apex of twig, scales with white ciliate margins. **Leaves** opposite, deciduous, simple; ovate to almost circular, 4 to 9 cm long, 2.5 to 7 cm wide, usually longer than broad; 3-lobed near the apex, margin finely serrate; dark green above, glaucous and lightly pubescent below, pubescence usually shed. **Flowers** typically polygamous, occasionally with perfect flowers, small, forming dense clusters from separate buds before leaf expansion, conspicuous because of the red to orange coloration. **Fruit** twin samaras 10 to 20 mm long.

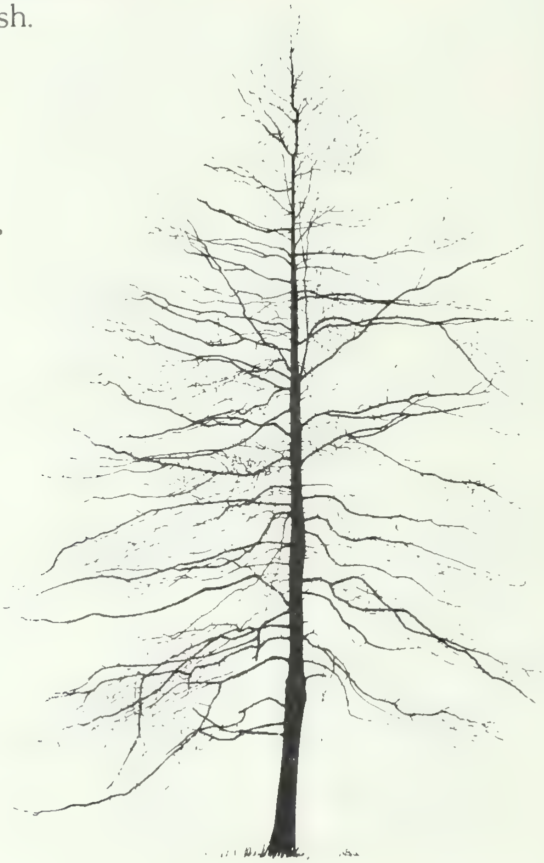
Var. *drummondii:* **Leaves** larger than typical red maple, usually broader than long; 3 to 5 lobes or occasionally scarcely lobed, margins coarsely toothed, conspicuously glaucous below, usually permanently tomentose. **Fruit** samaras 4 to 5 cm long.



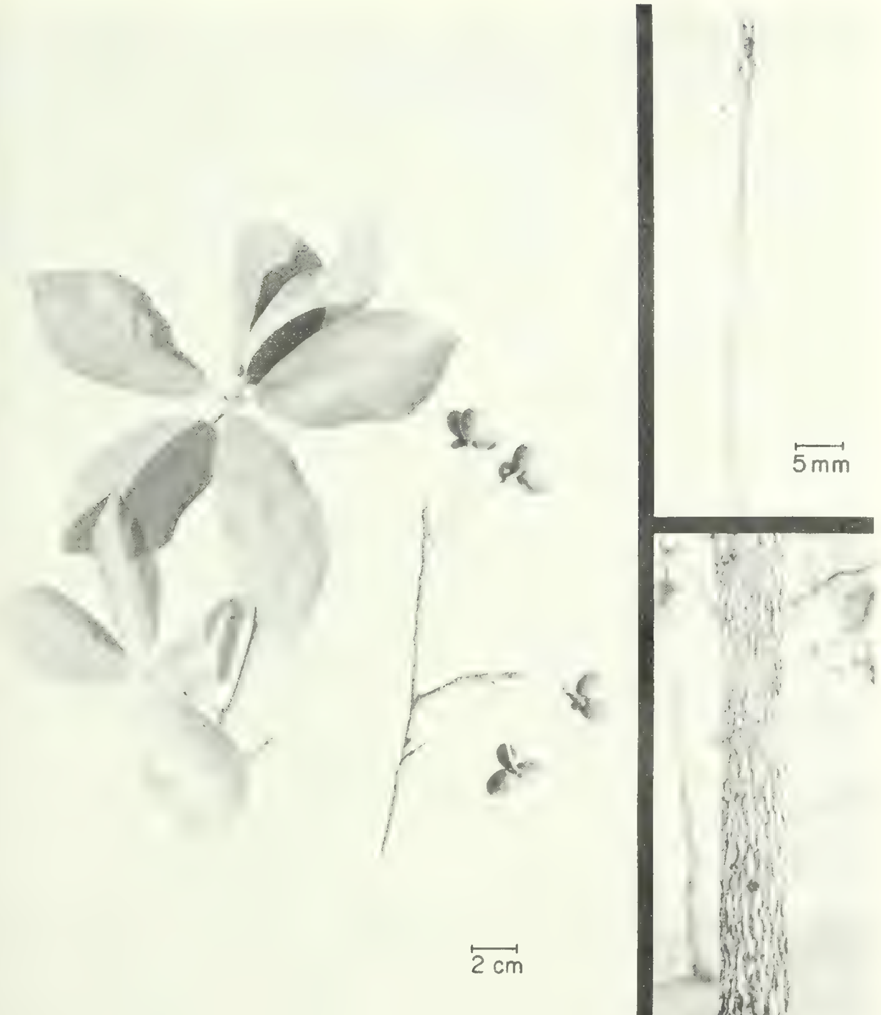
Red Maple/*Acer rubrum*

Black Tupelo; blackgum

Nyssa sylvatica Marsh.



Bark black, marked with furrows and cross-cracks that divide the ridges into squarish plates. **Branches** slender, spreading to horizontal, often drooping in open-grown specimens. **Twigs** 2 to 3 mm in diameter, gray to reddish. **Buds** obtuse, of overlapping yellow-brown scales, terminal buds 6 mm long. **Leaves** alternate, early deciduous, simple; marked with irregular black spots and purple coloration from midsummer on, elliptic to broadly oval to obovate, 5 to 15 cm long, 3 to 8 cm wide; apex acute to broadly rounded, margin entire, base wedge-shaped. **Flowers** unisexual, less than 4 mm in diameter, appearing in April before leaf expansion. **Fruit** a black drupe 8 to 10 mm long, 1 to 3 on pedicels 3 to 5 cm long, stone faintly ribbed.

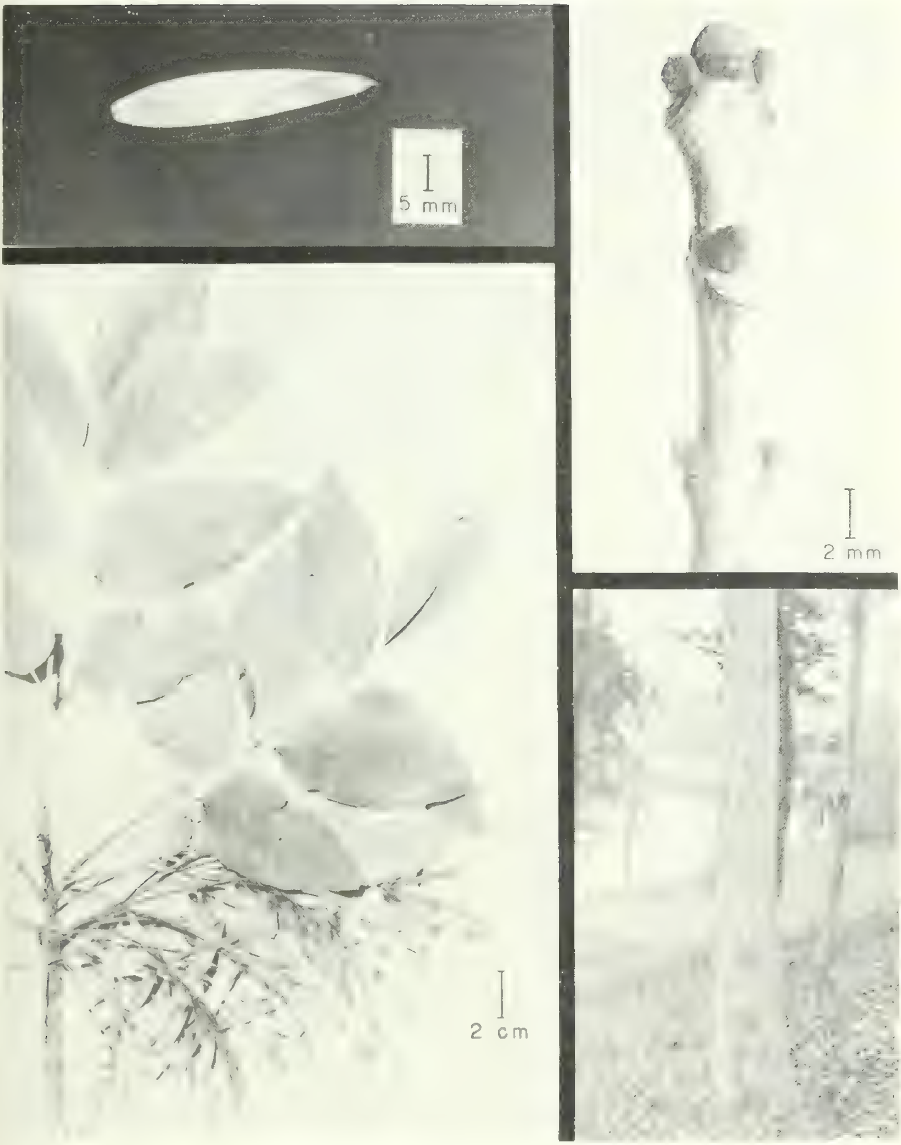


Black Tupelo; blackgum/*Nyssa sylvatica*

White Ash

Fraxinus americana L.

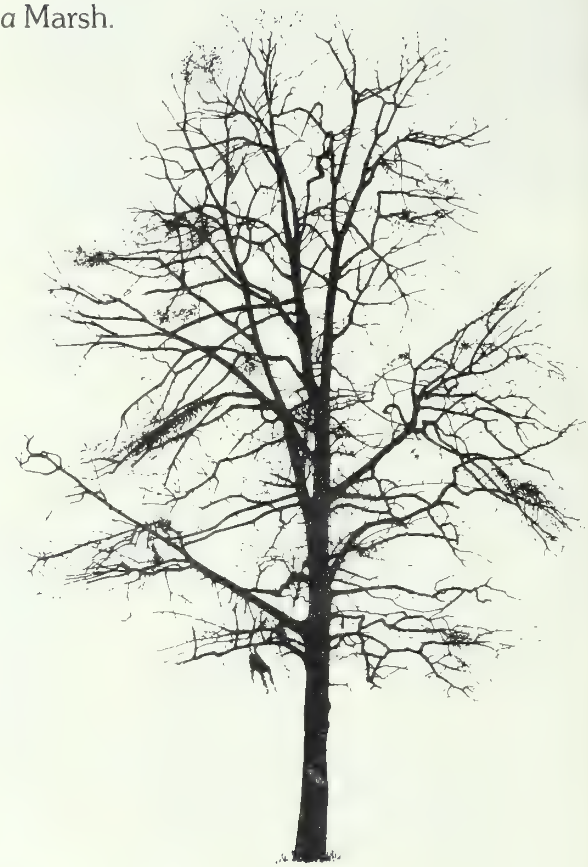
Bark gray to brownish, divided into narrow, deep furrows and ridges of equal width. **Branches** stout, wide spreading. **Twigs** 3 to 6 mm in diameter. **Buds** (terminal) broadly ovoid consisting of 4 appressed scales, dark brown to black, lateral buds spherical, tightly appressed to a crescent-shaped leaf scar. **Leaves** opposite, deciduous, odd pinnately compound, 20 to 30 cm long, white below when fresh, leaflets 7 to 9, petiolulate, oval to ovate, 5 to 15 cm long, 3 to 5 cm wide, apex acuminate, margin essentially entire, base broadly rounded, pinnate veins conspicuous on underside. **Flowers** unisexual (plants dioecious), pistillate inconspicuous about 1 mm in diameter, arranged in dense paniculate clusters, staminate conspicuous in mass. **Fruit** a samara, 25 to 60 mm long, wing terminal on the thickened seed.



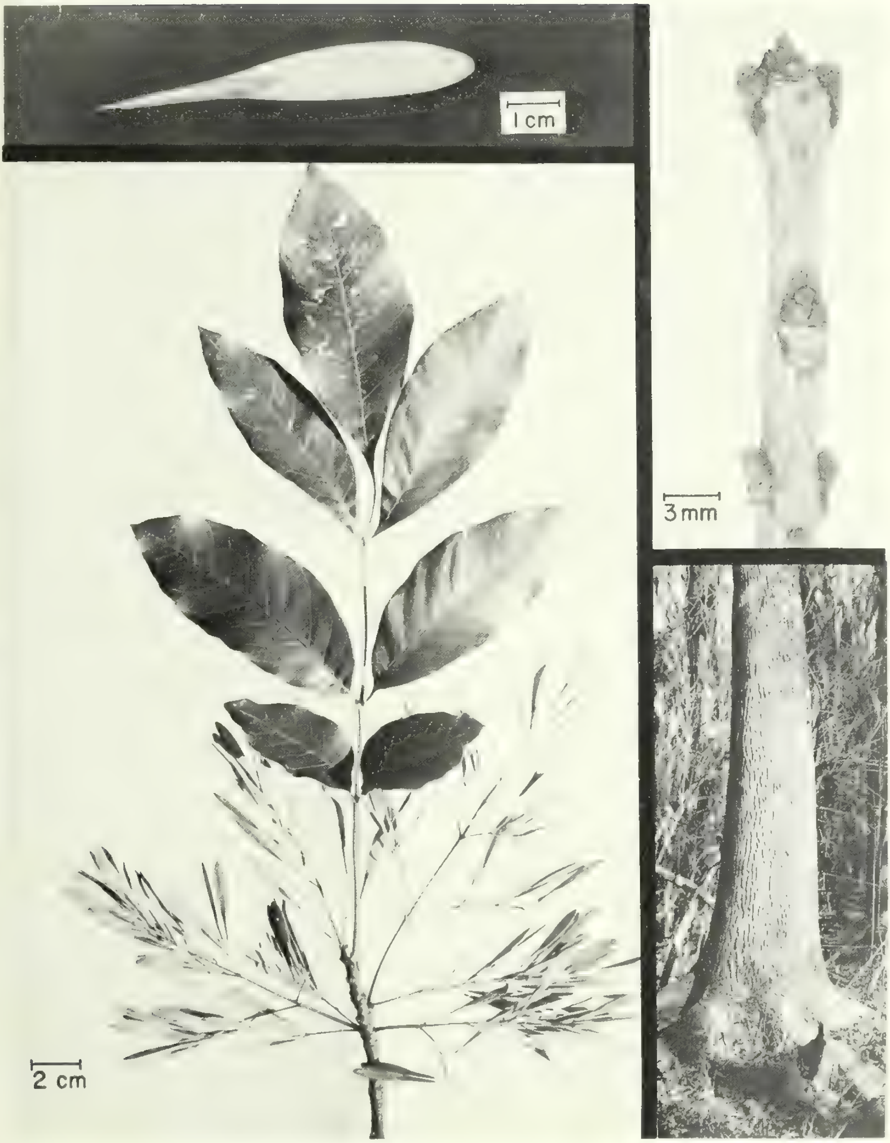
White Ash/***Fraxinus americana***

Green Ash

Fraxinus pennsylvanica Marsh.



Bark brownish, smooth when young, then breaking into narrow ridges with shallow narrow furrows. **Branches** drooping to spreading and ascending. **Twigs** stout, 4 to 6 mm in diameter, olive green. **Buds** terminal black, smaller lateral buds tightly appressed to the generally straight upper edge of the leaf scar. **Leaves** opposite, deciduous, odd-pinnately compound with 5 to 7, occasionally 9, leaflets; leaflets narrowly to broadly elliptical,apex acuminate, margin entire to finely serrate, base wedge-shaped, hairy below along the veins. **Flowers** unisexual (plants dioecious); pistillate inconspicuous in open panicles; staminate in compact conspicuous clusters. **Fruit** a samara 25 to 50 mm long, seed end conspicuously slender and extending about half the length of the samara, wing decurrent on seed end.



Green Ash/*Fraxinus pennsylvanica*

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GLOSSARY

Acuminate. Gradually tapering to a pointed apex.

Acute. Having the shape of an acute angle.

Aggregate. A cluster of ripened ovaries traceable to separate pistils of the same flower and inserted on a common receptacle.

Anther. The pollen-bearing portion of the stamen.

Anthesis. Time of flowering.

Apetalous. Without petals.

Apex. The tip of leaf, twig, or other plant part.

Apical. Pertaining to apex.

Ascending. Growing obliquely or indirectly upward from point of attachment.

Axil. Upper angle between a leaf or other plant part and the stem to which it is attached.

Bisexual. Having both sex organs on the same plant; a hermaphrodite.

Blade. The flat expanded portion of a leaf or parts of a compound leaf.

Catkin. A flexible, usually pendulous, scaly spike bearing unisexual flowers.

Ciliate. Having a margin fringed with hair.

Compound Leaf. A leaf with two or more separate leaflets.

Cordate. Heart-shaped with the point at the terminal end.

Crenate. Having a margin with rounded to blunt teeth.

Cuneate. Wedge-shaped.

Deciduous. Not persistent; said of leaves falling in autumn or of floral parts falling after anthesis.

Dehiscent. Opening by bursting or splitting.

Dentate. A margin with sharp teeth pointing outward.

Dimorphous. Occurring in two forms.

Dioecious. Unisexual, with staminate and pistillate flowers on separate plants.

Drupe. A simple one-seeded fleshy fruit, the outer wall fleshy, the inner wall bony.

Entire. Margins without teeth or lobes.

Evergreen. Having green leaves throughout the year.

Falcate. Sickle- or scythe-shaped.

Follicle. A dry, single-carpel fruit, opening along one side for seed dispersal.

Fluted. Regularly marked by alternating ridges and grooves.

Fruit. The seed-bearing product of a plant.

Glabrous. Smooth, devoid of hair or surface glands.

Glandular. Furnished with glands, or glandlike.

Glaucous. Covered with a white waxy or powdery bloom

Globose. Spherical, globular.

Husk. Fleshy covering of nut in hickories.

Imbricate. Overlapping.

Leaflet. A single division of a compound leaf.

Membranous. Thin, more or less flexible, translucent.

Midrib. The central rib or central vein of a leaf or similar structure.

Monoecious. Having unisexual flowers, with both sexes borne on the same plant.

Nut. A hard-shelled, indehiscent, usually one-celled, one-seeded fruit.

Oblique. Slanted; of unequal-sided or non-symmetrical leaves or leaf bases.

Obovate. Inverted ovate.

Obpyriform. Inverted pear-shaped.

Obtuse. Blunt.

Odd Pinnate. Pinnately compound with a terminal leaflet.

Ovate. Having the lengthwise outline of an egg, broadest at the base.

Ovoid. Egg-shaped in 3-dimensions.

Ovule. An embryonic seed in the ovary of a flower.

Palmate. With veins or lobes radiating from a common center.

Panicle. A compound or branched raceme.

Paniculate. Borne in a panicle.

Parted. Divided by sinuses which extend nearly to the midrib.

Perfect. Having stamens and pistils in the same flower.

Persistent. Remaining attached.

Petiolate. Having petioles, not sessile.

Petiole. The stalk of a leaf.

Petiolulate. Having petiolules.

Petiolule. The stalk of a leaflet in a compound leaf.

Pinnate. Descriptive of compound leaves with the leaflets arranged on opposite sides along a common rachis. Also used to describe leaf venation.

Pistil. The seed-bearing organ of the flower.

Pistillate. Provided with pistils; usually descriptive of unisexual flowers.

Polygamous. Bearing perfect and unisexual flowers on the same plant.

Polymorphic. Having two or more forms.

Pubescent. Covered with fine, soft, short hairs.

Pyriform. Pear-shaped.

Raceme. An inflorescence consisting of a central rachis bearing a number of flowers with stalks of nearly equal length.

Rachis. The axis of a compound leaf or inflorescence.

Receptacle. The portion of the floral axis upon which the flowers are borne.

Reticulate. Forming a network.

Rhombic. Somewhat diamond-shaped.

Rib. A prominent vein.

Samara. An indehiscent winged fruit.

Scurfy. Covered with small scales.

Seed. A ripened ovule.

Serrate. With sharp teeth pointing forward.

Sessile. Without a stalk of any kind.

Simple. Of one piece; not compound.

Sinuate. Deeply or strongly undulate or wavy.

Sinus. A recess, cleft, or gap between two lobes.

Spatulate. Spatula-shaped.

Spike. An inflorescence consisting of a central rachis bearing a number of stalkless flowers.

Stamen. Pollen-bearing organ of the flower.

Staminate. Bearing stamens.

Stellate. Star-shaped.

Stipule. A leafy appendage attached to the twig at the base of a petiole; usually in pairs, one on each side, often shedding early.

Striate. With fine grooves, ridges, or lines of color.

Suture. Line of dehiscence.

Subglobose. Globe shaped, but slightly flattened.

Subsessile. Almost stalkless.

Tomentose. Coated with short, matted woolly hair.

Truncate. Having a blunt tip or end, appearing as if abruptly cut off transversely.

Undulate. Wavy.

Unisexual. Having stamens and pistils in separate flowers.

Valvate. Opening by valves as in a capsule or some leaf buds; meeting at the edges without overlapping.

Whorl. Circular arrangement of appendages at a node.

Woolly. Clothed with long, matted hairs.

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This publication illustrates and describes 26 hardwood species or varieties, including 16 oaks and hickories, with photographs of leaves, bark, buds, flowers, and fruits. Line drawings feature the winter silhouette of each species and a key is included to assist in identification.

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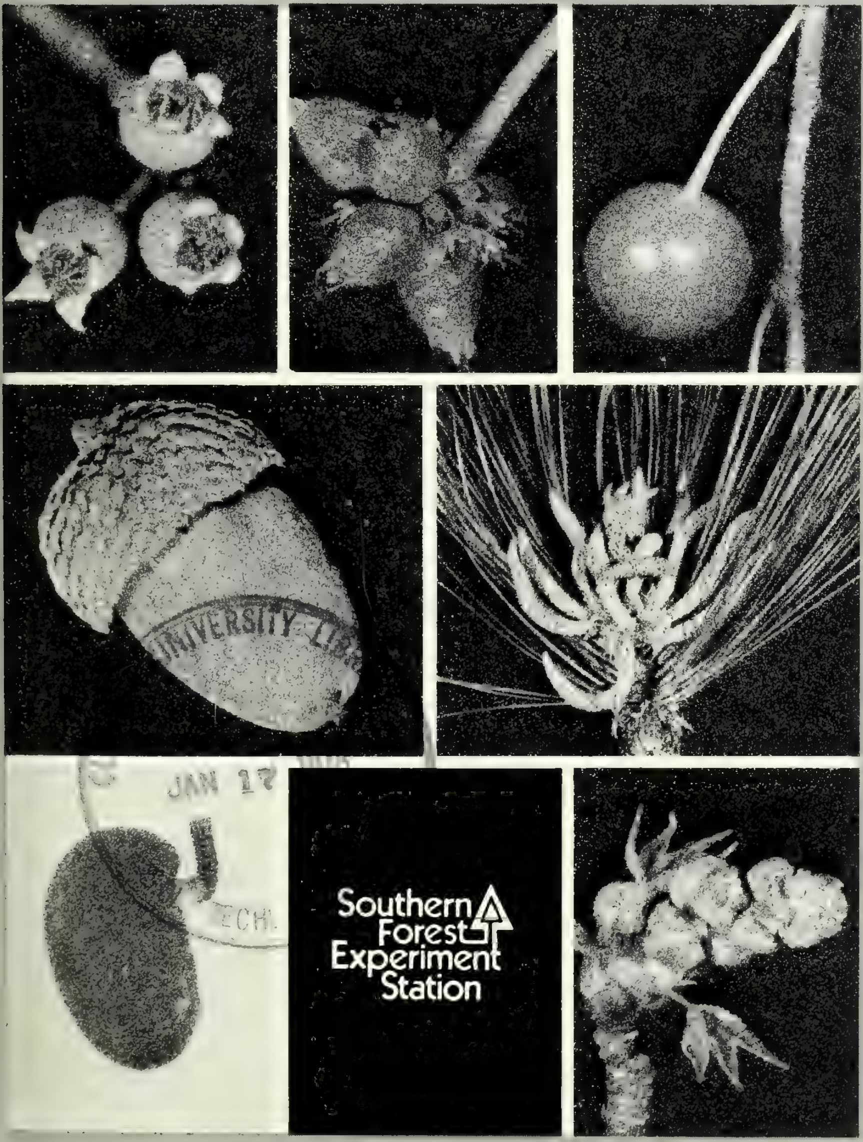

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FOREWORD

his publication describes and provides illustrations of 106 woody plant pecies that produce fruit useful to wildlife in southern forests. Information about plant growth requirements, management, and nutritional uality are also included. Trees, shrubs, and vines that produce fleshy ruits or nuts are emphasized because their fruits are a vital source of ood for many animals.

The area of consideration extends from eastern Texas and Oklahoma, eastward to Virginia, south to Florida, and encompasses bout 200 million acres of forest. Major forest types that characterize he area are: white pine-hemlock, cedar, longleaf-slash pine, loblolly-hortleaf pine, oak-pine, oak-hickory, and oak-gum-cypress. The main eographical provinces are Coastal Plain, Appalachian-Piedmont lateau, Ouachita-Ozark Highlands, and Appalachian Mountains.

The climax vegetation of the entire area is oak-hickory, but mainly s a result of fire and of cultural manipulation by man, most upland reas in the Coastal Plain and Piedmont are dominated by pines. ecause pines are intolerant of shade these stands are usually even-aged. In bottomlands and mountains where fires are excluded, hardwood stands usually are even-aged although the dominant species are ntermediate to tolerant of shade.

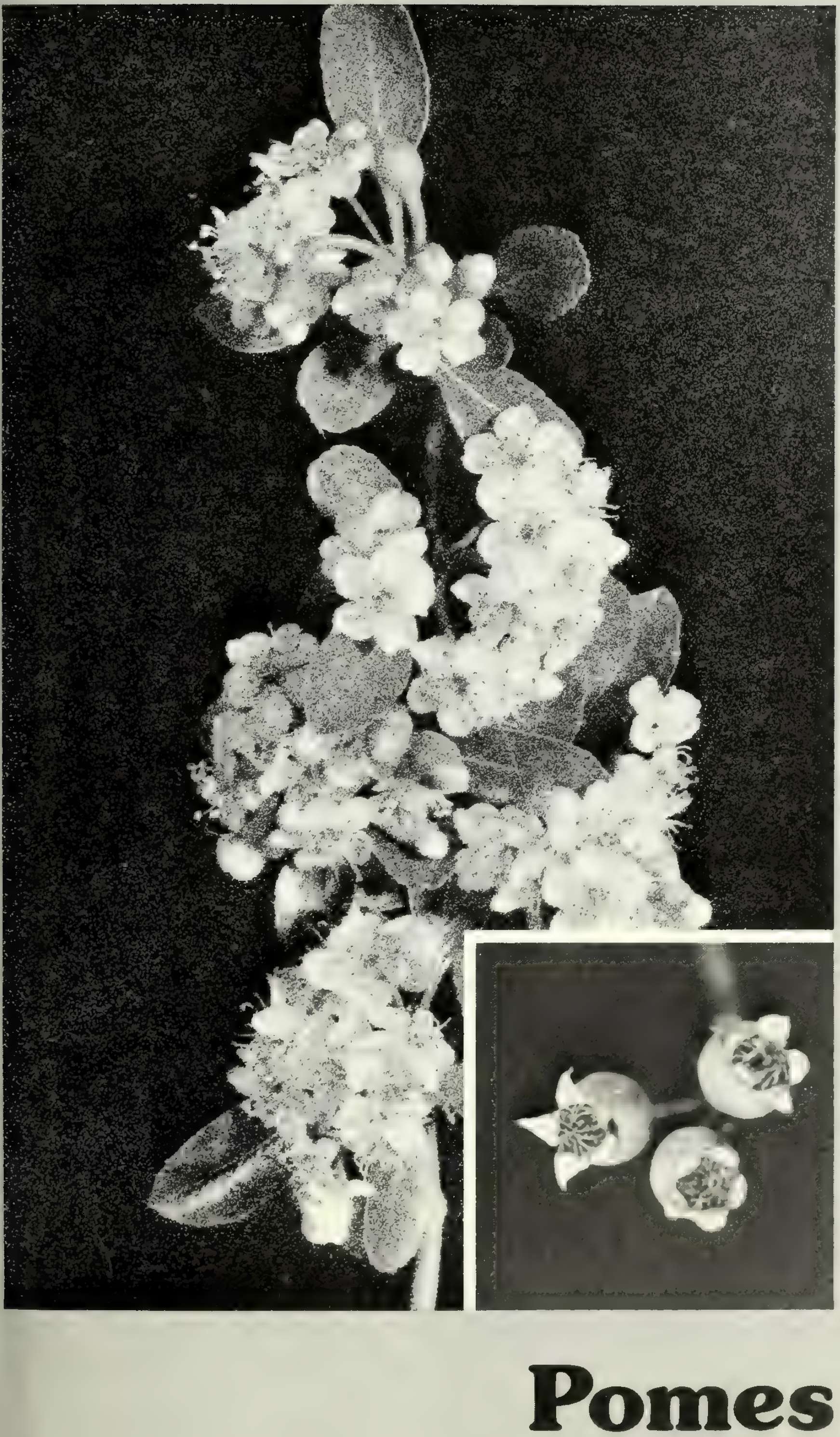
Forests managed primarily for timber have the potential to sustain much wildlife when management is directed toward increasing the mount of fruit available. Trees grown in stands that are open have well developed crowns and produce more fruit than trees with narrow rowns that grow in dense stands. Understory plants growing in light o moderate shade begin fruiting when they are younger and produce uit crops more consistently than plants growing in deep shade. Age f the trees affects productivity; trees in the middle of their lifespan roduce more fruit than either young or old trees. Prescribed burning ncreases fruit production of many understory species, but for other pecies destroys or seriously reduces the capacity to produce fruit. inally, genetically superior trees may grow 20 to 30 percent faster han unimproved trees, and it is likely that fruit production can be creased correspondingly.

The variety of fruits is as important to wildlife as the abundance. When many kinds of plants are present fruits are likely to be available ear around, stands produce fruits consistently year after year, and the abitat will meet the needs of many wildlife species. The presence of a variety of fruits helps animals obtain a balanced diet, especially in the South where many forages are deficient during several months of the year.

The Appendix table presents chemical composition values of fruit and seeds for species about which data are available. Exact compariso between species should be made with caution because of differences in analytical procedures and the time and place of collections. Nevertheless, the data are indicative of relative nutritional values and should serve as useful guides in habitat evaluation and management. In the text, nutrient content in percent of dry matter is according to the following classification:

	High	**Medium**	**Low**
Crude protein	≥13	8-12	≤7
Crude fat	≥7	4-6	≤3
Crude fiber	≥24	17-23	≤16
Nitrogen-free extract (NFC)	≥60	51-59	≤50
Phosphorus (P)	≥0.26	0.13-0.25	≤0.
Calcium (Ca)	≥1.00	0.21-0.99	≤0.

It is hoped that this paper will help the forest land manager to identify some of the more important fruit-bearing woody plants and that the information will enable him to do a better job of management



Pomes

POMES

Pomes are fruits that have several tough papery-walled cavities each containing seed, and the cavities are surrounded by thick flesh. These fleshy fruits may be large, as are apples, or small and berry-like as are the fruits of the hawthorn.

Fresh pomes have high moisture contents, and on a dry-weight basis, are usually very high in carbohydrates but low in crude protein. Most of them are edible to both humans and wildlife.

The genera discussed here are all members of the Rosaceae family.

Serviceberries/*Amelanchier* spp.

Joseph F. Larson
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There are five species of serviceberries in the southern United States. Allegheny serviceberry (*A. laevis* Wieg.), a shrub or small tree of up to 40 feet tall, grows on dry open woodlands, and in roadside thickets, cool ravines, on hillsides, or on damp wooded slopes and banks. Downy serviceberry [*A. arborea* (Michx. f.) Fern.], a shrub or small tree of up to 25 feet tall, is found in dry woods and open ground, and on wooded hillsides. Thicket serviceberry [*A. obovalis* (Michx.) Ashe], a slender shrub that forms colonies, occurs in open woods on sandy pine barrens along the Coastal Plain. Dwarf serviceberry [*A. spicata* (Lam.) K. Koch.], a stoloniferous shrub, grows on gravelly or rocky shores, sandstone or limestone cliffs, and ledges, in woods or thickets, and on pine barrens, or sand dunes. Shadblow serviceberry [*A. canadensis* (L.) Medic.], grows in clumps up to 20 feet tall, chiefly in swamps and bogs and on low grounds in woods.

When growing together several Amelanchier species will hybridize freely, making positive identification difficult. All of the species have several to many showy white or pinkish flowers that appear in advance of the foliage or with it. The leaves are simple, deciduous, alternate, pinnately veined, usually serrate, and elliptical or oblong in shape. The genus is illustrated in this bulletin by shadblow serviceberry, the species most often reported as a wildlife food plant.

Serviceberries are valuable wildlife food plants. The fruits are readily eaten by many species of songbirds during the early summer. The twigs, foliage, and flowers are consumed by white-tailed deer. Rabbits feed on the twigs. Ruffed grouse eat the fruits in fall and the buds in spring. Beaver, red fox, the eastern flying squirrel, and the eastern red squirrel consume the fruit, bark, and twigs. Chipmunks and bears relish the fruits. Cottontails feed on fallen fruits. Songbirds utilize the fruits adhering to branches in the winter. Fruits are high in nitrogen-free extract and low in crude fiber. Of the serviceberries, downy serviceberry fruits are the least edible.

Serviceberries are often grown for their showy early white flowers and edible fruits. Seeds should be collected immediately when ripe before being eaten by birds. Seeds can be planted in fall, but for spring planting they should be stratified in peat at 33° to 41°F for 90 to 120

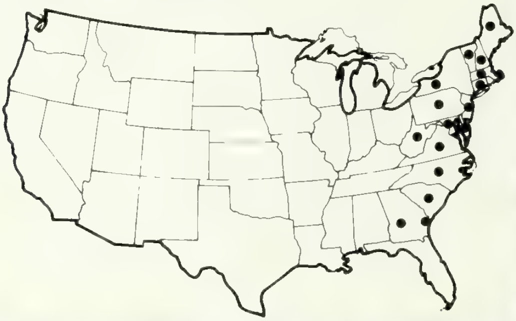
Shadblow Serviceberry

A shrub, usually with several upright trunks up to 20 feet high, growing in clumps.

Leaves alternate, simple, deciduous, 1 to 2.50 inches long. 0.70 to 1.10 inches wide, finely serrate on the margin, white tomentose beneath when young.

Flowers white, appearing with leaves, late March (southeast) to early June (northeast).

Fruit a blackish, juicy, sweetish berrylike pome, 0.33 inch in diameter.



days. Seedlings are usually transplanted at 1 year in the nursery and field planted 2 or 3 years later. Plants can also be propagated by cuttings in the fall, or from suckers in the spring.

Serviceberries are usually welcome vegetation. In addition to their high aesthetic value and their importance as wildlife food, their fruits are edible to humans. Also, some of the larger species are used for wood products, such as handles.

Other common names for the genus are Juneberry, shadblow, and shadbush. In the eastern and northeastern states the term shad probably comes from the flowering of these species at the same time that shad begin to ascend streams in spring.

***Hawthorns*/*Crataegus* spp.**

Paul A. Shrauder
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The hawthorns are easily recognized as a group, but species are extremely difficult to identify, even by specialists. Because of great variation among individuals and probable prolific hybridization, the number of species has been variously listed from 100 to over 1,200. Most authorities recognize about 800 species.

The shrubs or small trees range in height from 2 to 40 feet. The leaves are alternate, simple, serrated or lobed, deciduous, lustrous, dark green in color, and usually have a rubber-like texture. The characteristic stiff and sharply pointed thorns range from 0.5 inch to 6 inches in length. The perfect, showy, white, or rarely pinkish flowers are usually borne in terminal, cyme-like clusters. Flowers usually bloom in April and May, and their strong almond-like fragrance aids immensel in insect pollination.

The small, apple-like fruits are bright red, yellow, green, or black in color. They are generally open and concave at the apex and are borne in branched clusters. The flesh is usually dry and unpalatable, but in some species it is tart and palatable. Fruits contain from one to five bony seeds that are widely disseminated by both birds and mammal Because of their thick shells, the seeds are slow in germinating, often "lying over" for a season.

The twigs are moderate or slender, more or less zigzag and marked by oblong, mostly pale lenticels. Light green when they first appear, the twigs later become red, lustrous orange-brown, or gray. Leaf scars are horizontal, slightly elevated, narrowly crescent-shaped, and show three bundle scars. The winter buds are rather small, roundish or bluntly pointed, generally smooth, and reddish or bright chestnut in color, and have many overlapping, exposed bud scales.

Hawthorns occur on a wide variety of sites and on soils ranging from heavy clay to sandy loam. Several hawthorns attain their best development on dry stony ridges and mountain slopes; others flourish in moist river bottoms and along the edges of swamps, mostly in neutral soil.

Hawthorns are intolerant, and most species represent an early stage in plant succession. They seed into openings quickly and are

Blueberry Hawthorn

A beautiful round-topped tree attaining a height of 40 feet, armed with short curved spines.

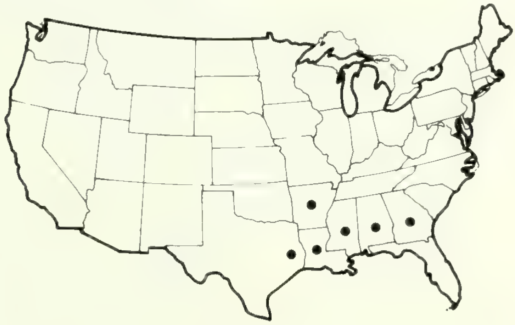
Leaves have serrate margins, are sometimes lobed, dark green glabrous and lustrous above, paler and glabrous beneath, 0.75 to 3.50 inches long, 0.50 to 2 inches wide.

Twigs green and minutely pubescent at first, glabrous and reddish brown to gray later, spines 0.33 to 0.66 inches long, stout, curved, and gray to brown.

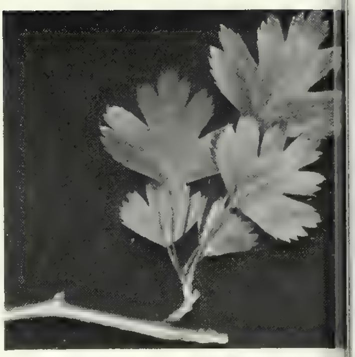
Flower borne in many-flowered corymbs, 0.33 inch across, white at first and orange later.

Fruit bright blue or black with glaucous, 0.33 to 0.50 inch long, thin flesh, three to five nutlets. August.

Other common names: ***blue haw, pomette bleue.***



Parsley Hawthorn



A shrub or small tree 15 to 25 feet high, scaly bark.

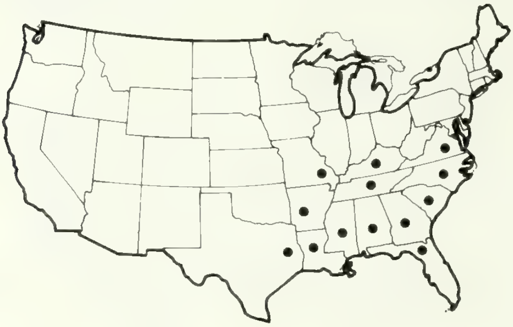
Leaves broadly ovate, sharply serrate, deeply incised, pubescent when young. At maturity, thin, glabrous above, pubescent along veins below, 0.75 to 1.50 inches long.

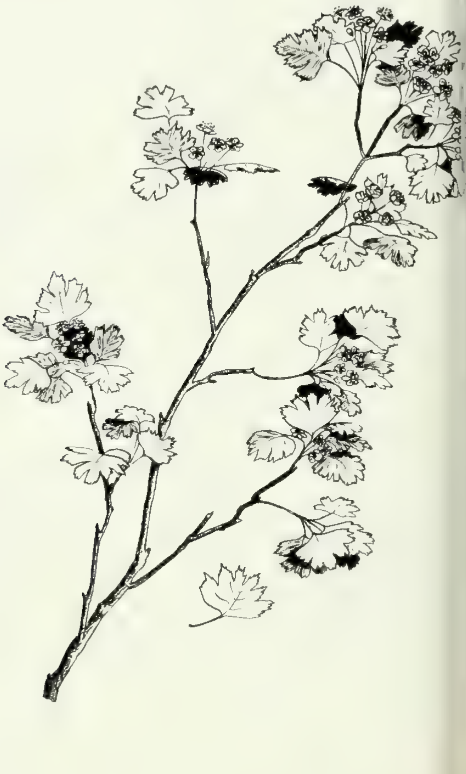
Twigs thorny, pubescent when young; spines 1 to 2 inches long.

Flowers 0.50 to 1 inch wide, white, almond-like fragrance. April.

Fruit 0.50 inch in diameter, bright red, thin succulent flesh, one to three nutlets. October.

Other common names: ***parsley haw, parsley-leaved thorn.***





frequently found in abandoned fields, pastures, and meadows. Although most numerous in areas around livestock farms, the plants also occur along the edges of or within moderately dense pine and hardwood forests. Their long sharp thorns help protect them from livestock grazing, and the long taproot helps them survive extended droughts.

Hawthorns are frequently a deterrent to timber regeneration and early growth. Impenetrable thickets, however, may be gradually invaded by shade tolerant trees. Maintenance of the hawthorn thickets consists mainly of controlling or eliminating the invading species of plants, usually by selective cutting.

Fruits of hawthorns are eaten by several kinds of songbirds, particularly the sparrows and cedar waxwing, and by game birds such as wild turkey, bobwhite quail, and wood ducks. Hawthorns are a key item in the fall diet of ruffed grouse. Squirrels, foxes, raccoons, rabbits, white-tailed deer and rodents eat the fruit quite extensively. The fruits are relatively low in crude fiber. Some species retain their fruits over winter, but on others fruits mature and drop in early spring. The browse is considered fair in palatability for deer, and is most heavily used in May and June.

Hawthorn stands serve as important brood-rearing areas for ruffed grouse and wild turkeys and as excellent cover for woodcocks. Hawthorn also provides nesting sites for many birds such as brown thrashers, catbirds, robins, blue jays, and mourning doves.

Hawthorns are occasionally attacked by several pests. Tent caterpillars, fall webworms, and canker worms eat foliage, and aphids and mites injure it. Apple borers may injure the trunks and leafminers are found on foliage and fruit. Usually, however, the damage from such pests is not serious. Most hawthorns are highly susceptible to rust, with redcedar as the alternate host.

Because of their showy flowers and fruits, hawthorns are often planted in parks and gardens. The fruits of some species, particularly riverflat hawthorn, are often picked by humans and made into wine or jelly.

Plants are easily transplanted from the wild when young. Older plants have deep taproots that are hard to dig, and are less sure to survive transplanting. Nursery stock is available for planting but is expensive.

For wildlife purposes, the most practical way to establish hawthorn thickets is by seeding. Seeds should be cleaned, stratified in sand over winter, and planted in spring. The number of seeds per pound ranges from 6,000 to 40,000 with about 40 percent germination. Because of

Riverflat Hawthorn

A deciduous shrub to small tree.

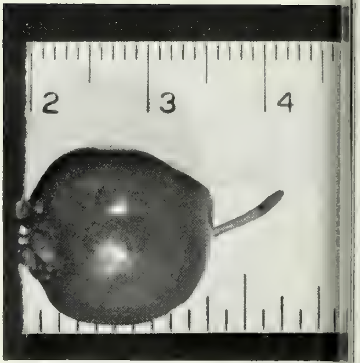
Leaves dark green and usually glabrous above, rusty brown and pubescent below.

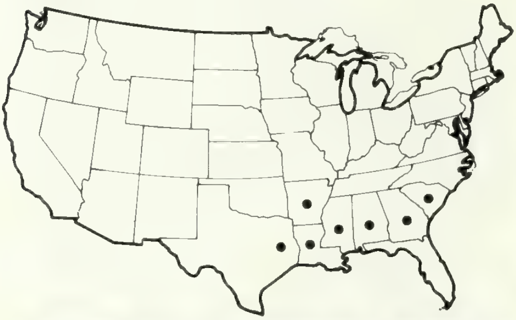
Twigs brown to reddish brown to grey, scattered white pubescence when young, becoming glabrous, spines up to 1.50 inches long; buds small, round and glabrous, reddish in color, leaf scars slender and flat V-shaped, hard pith.

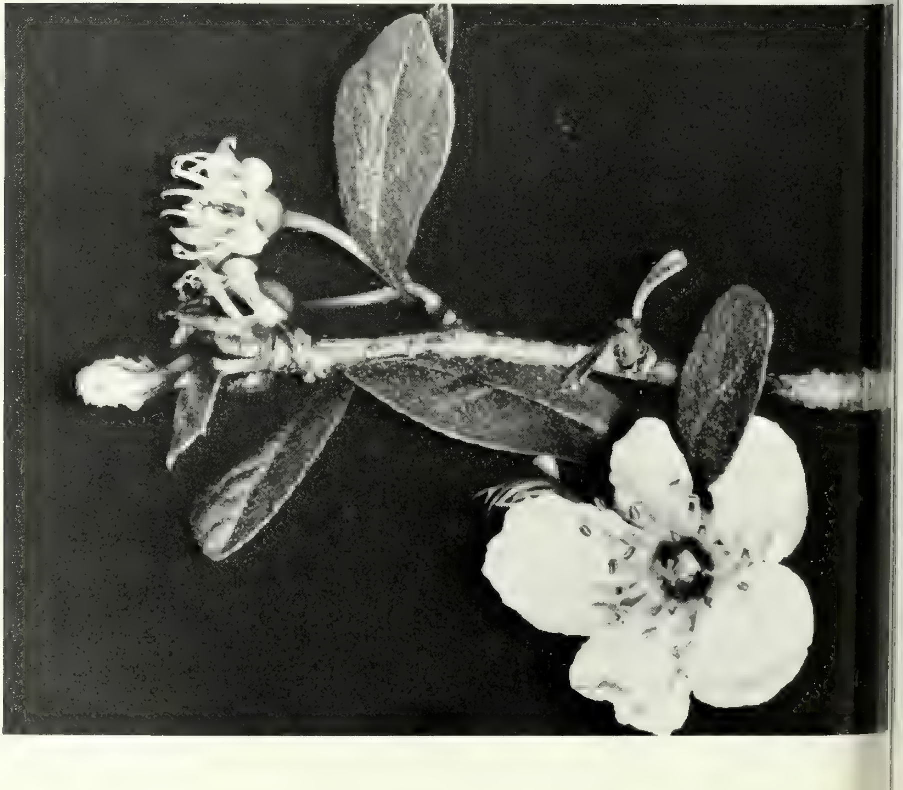
Flowers white, borne before leaves. February to March.

Fruit red, three to five nutlets. April to May.

Other common name: ***May haw.***







One-Flower Hawthorn

A slender shrub 3 to 12 feet high.

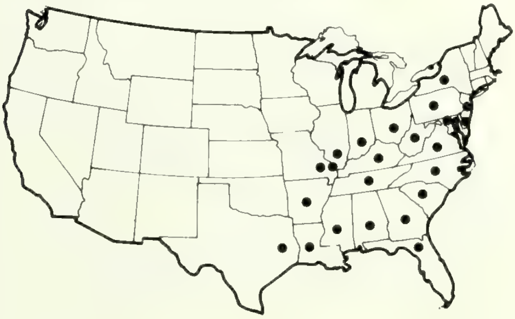
Leaves sharply serrate, upper surface dark green and lustrous, with scattered hairs; lower surface pubescent.

Twigs reddish brown to gray and densely pubescent when young, older twigs are gray and glabrous, spines slightly armed or straight, 0.50 to 2.25 inches long.

Flowers on short, tomentose pedicels, white, two or three together or single. May.

Fruit usually solitary, 0.36 to 0.50 inch thick, pubescent, greenish yellow to dull red, fleshy dry and firm, three to five nutlets. October.

Other common name: ***Dwarf thorn.***



rust, hawthorns should not be planted in areas where redcedar is abundant.

Four species of hawthorns are illustrated here:

(1) Blueberry hawthorn (*C. brachyacantha* Sarg. and Engelm.) is a small tree that grows along margins of streams and swamps. It is distinguished from other species by its blue fruit which ripens in August.

(2) Parsley hawthorn (*C. marshallii* Eggl.) grows in open woods and low hills, usually along streams.

(3) Riverflat hawthorn (*C. opaca* Hook & Arn.) is found in wet soil around shallow ponds. It is the famous May haw of the South. The large size and acid character of the fruit are particularly desirable for jelly. Buds are eagerly sought by squirrels in spring.

(4) One-flower hawthorn (*C. uniflora* Muenchh.) is a shrub that grows in woods or on sandy or rocky banks.

Common Apple

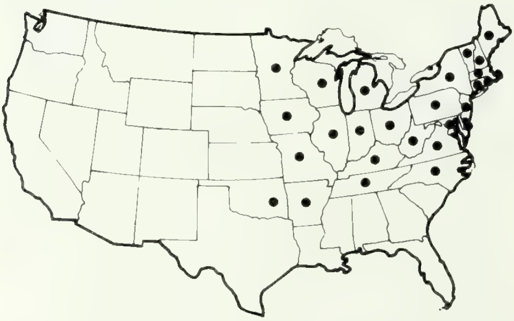
A small tree, 15 to 50 feet tall with a short trunk and spreading branches.

Leaves alternate, margin finely serrate; blade 1 to 4 inches long, 0.75 to 3 inches wide; upper surface dull green, glabrous; lower surface paler and pubescent.

Twigs stout, reddish-brown, glabrous, lustrous; branchlets short and spurlike.

Flowers in terminal cymes, pinkish-white. May to April with leaves.

Fruit a fleshy pome, 1.33 to 4 inches in diameter, green to yellow to red, five papery locules in flesh, two seeds in each locule. September to November.



Common Apple/*Pyrus malus* L.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

The common apple is an introduced species that escaped from cultivation and is frequently found on old fields, clearings, and abandoned home sites. It grows in a wide variety of soils and climates but does best on clay-loam soil.

The fruits and seeds are eaten by upland game birds, including the bobwhite quail and mourning dove, and by many kinds of songbirds. The fruits are a favorite fall and winter food for ruffed grouse, which also eat the buds in spring. The fruit and bark are eaten by fur and game animals, particularly oppossums, raccoons, and foxes. White-tailed deer eat the fruit, foliage, and twigs. Some damage occurs by pecking of fruit by birds and the eating of bark of both trees and saplings by rabbits and mice.

Most of the commercial apples are propagated vegetatively.

Other common names: Pommier, scarb-tree, wilding-tree, crab-tree, crab apple.

Drupes

A drupe is a fleshy or pulpy fruit in which the inner ovary wall (endocarp) is hard and stony, enclosing a seed. Cherries and plums are good examples.

DRUPES

Drupes are extensively eaten by wildlife and many are important for human consumption. Usually the fruits are low in crude protein and high in carbohydrates, but the nutrient contents vary quite widely among species. Some members are high in prussic acid and may be dangerous to humans and livestock.

The genera discussed here are members of several family groups.

Alabama Supplejack

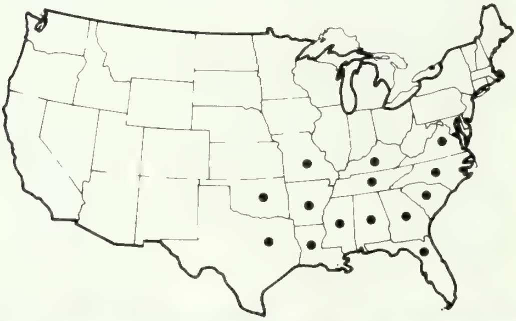
A high climbing, large, twining vine.

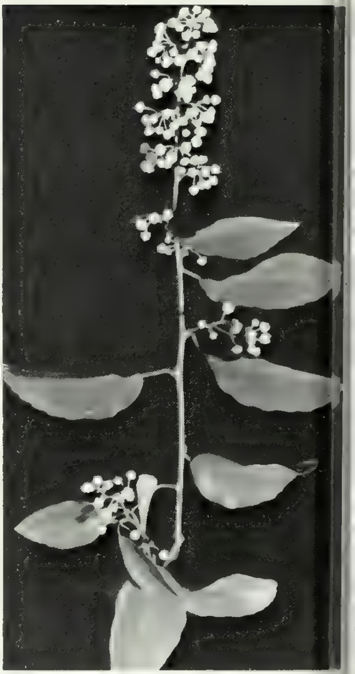
Leaves alternate, dark green, glabrous, 1.50 to 3 inches long and 0.75 to 1.50 inches broad.

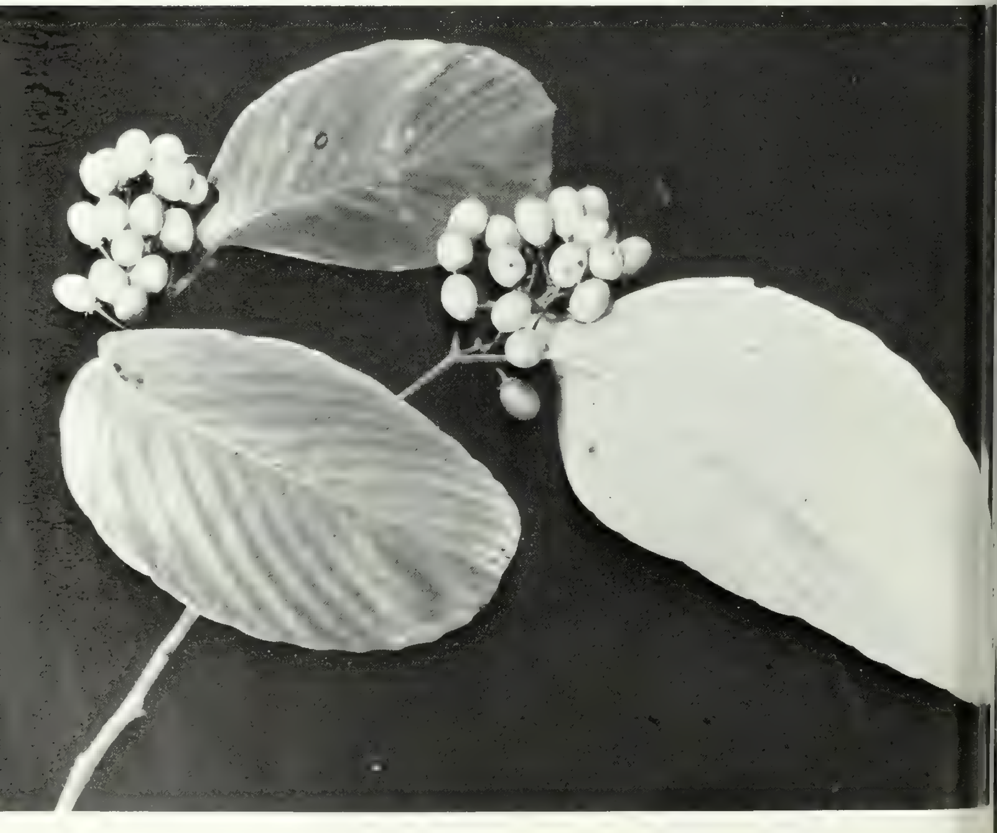
Twigs are much branched, slender, green and gray streaked to brown when young and reddish brown or black when older.

Flowers are greenish-yellow. March to June.

Fruit is a bluish-black drupe, 0.25 to 0.33 inch long. July to October.







***Alabama Supplejack*/*Berchemia scandens* (Hill) K. Koch**

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Growing in rich moist soils, this high-climbing vine encircles and quickly grows to the tops of trees or whatever support is present. The strong, pliable stems may girdle and kill large trees.

The fruits of Alabama supplejack are eaten by many kinds of birds, including wild turkey, bobwhite quail, and mallards, and by small mammals such as raccoons and squirrels. White-tailed deer eat both the fruits and the foliage. The heaviest use of Alabama supplejack browse twigs occurs in spring and summer. When forming hedges or thickets along fences, the species provides excellent nesting area and escape cover for rabbits and birds.

Alabama supplejack plants growing in the open consistently produce fruit annually. Ripened fruits persist on plants through most of the winter; thus, they are a source of food at a critical period. The fruits are low in crude protein and phosphorous, high in crude fiber, and moderately high in calcium.

Alabama supplejack grows well beneath trees, but forage and fruit yields are several times greater when plants grow in the open. The plants withstand prescribed burning in winter, which is the practice that is usually recommended for keeping the plant growth close to the ground. If left unchecked, most of the foliage soon grows beyond reach of deer.

The strong pliant vines are often used in wickerware.

Other common name: rattan vine.

American Beautyberry/*Callicarpa americana* L.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

This deciduous shrub thrives on a wide variety of forest sites. It grows well in shade but does best in the open or beneath high, fairly thin pine canopies. In late March, it puts out new green leaves oppositely arranged on the twig. Twig growth is essentially completed by July, but when portions of the current season's growth are removed some of the lateral buds break dormancy and form new twigs. The rootstocks resprout if the stems are killed by woods fires. The plants do not compete with trees being grown for saw logs or pulpwood.

Small bluish flowers form in the leaf axils mostly during June but occasionally through the summer. The conspicuous berries, the real trademark of the plant, become noticeable in June and mature from August to September. Many persist to January.

The fruits are important quail food during the winter, and are frequently eaten by deer from August through October and to a lesser extent at other times of the year. They are also eaten by squirrels, raccoons, opossums, foxes, and domestic livestock.

The fruits are readily available in August and September, a time when other wild fruits are scarce. Furthermore, their high water content (about 80 percent) can be important to wildlife during these usually dry months.

In an east Texas study, American beautyberry yielded more fruit than 13 other species during a 10-year period. In the open, plants grew rapidly the first few years and produced abundant fruit. Yields peaked at 1,722 grams per plant, when plants were 5 years old. The following year, however, the plants deteriorated and many stems died back. This general decadence continued for 2 years, and fruit yields declined to 107 grams. The next year many of the old stems sprouted at the base, and the plants again produced a substantial fruit crop. During the next 2 years, severe dieback of stems diminished fruit yields. In the woods, young plants developed more slowly, produced less fruit, and after plant were 5 years old the fruit yields tended to be high and low in alternate years. Differences in fruit yields between open- and woods-grown plants lessened as they became older, and at age 12 yields were similar to eac other.

The twigs and leaves are eaten by deer and cattle during the growing season and occasionally in early winter. As a deer browse plant American beautyberry is considered medium in preference, but as with other medium preference plants it may be a major part of a deer's

American Beautyberry

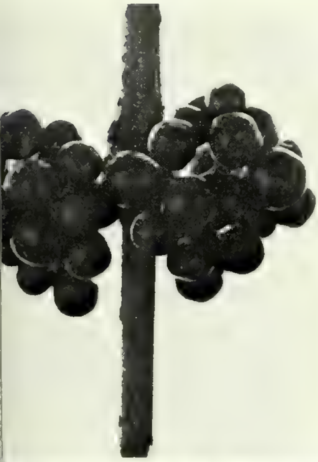
A much-branched shrub commonly 2 to 8 feet tall.

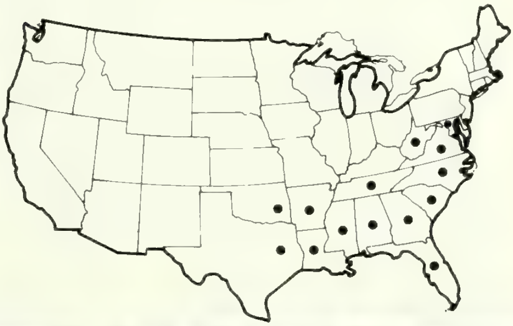
Leaves deciduous, white pubescent below, soft-textured, aromatic, 3 to 9 inches long, 1.50 to 5 inches wide.

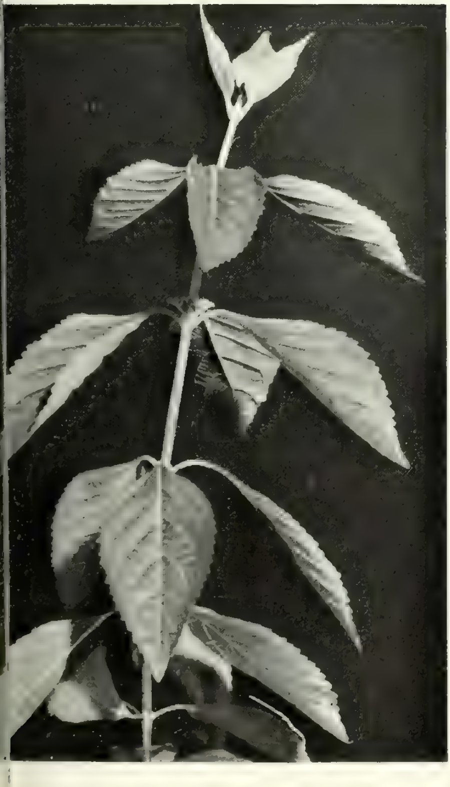
Flowers small, bluish, clustered in leaf axils. June.

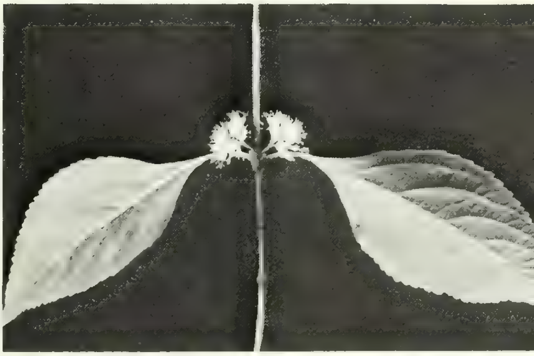
Fruit is a purple berry-like drupe with four seeds, each about 0.03 inch long. August to September, persist to January.

Twigs round or four-sided, densely hairy.









diet when highly preferred foods are scarce. When deer and cattle use the plants very heavily, browse and fruit yields are likely to be lessened, but the plants are seldom killed.

Fruits are relatively low in crude protein and phosphorus, and medium in nitrogen-free extract and calcium.

During the period of rapid growth in spring, the new leaves and twigs have enough crude protein, phosphorus, and calcium to meet the maintenance and growth requirements for both deer and cattle. When growth ceases, the protein and phosphorus content drop below the amount needed by the animals but the calcium remains adequate. Leaves and twigs from a plant that has been through a recent fire are higher than average in nutrient content and palatability.

American beautyberry is easily propagated. Seed collected in the fall can be sown in the field or nursery the next spring. Plants grown in the nursery can be outplanted the following winter. Losses from transplanting are usually few. The plants also are easily rooted from stem cuttings. The best time to take cuttings is September. If cuttings made then are propagated in the greenhouse they can be outplanted in late winter and will produce fruit the following summer. American beautyberry is best maintained by a moderate disturbance such as logging and readily sprouts after a winter burn.

American beautyberry is an attractive plant for yards and parks. Its brightly colored fruit, the ease with which it can be propagated, and its ability to grow in the shade and on a variety of sites with very little culture all add to its popularity.

Other common names: Spanish-mulberry, French-mulberry, Bermuda-mulberry, sour-bush, and sow-berry.

Sugarberry

A tree up to 100 feet high and 2 feet in diameter.

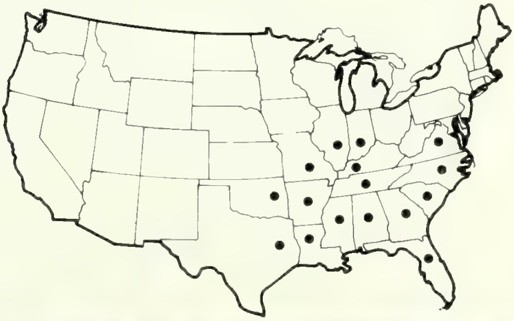
Crown spreading and round-topped or oblong. Bark thin, smooth, with prominent warty growths.

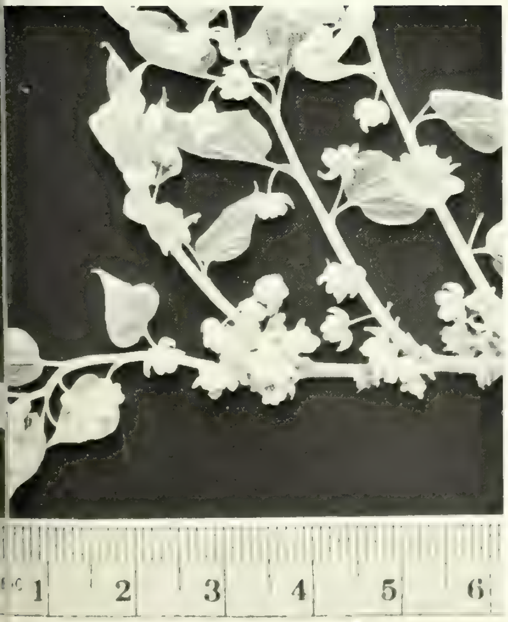
Leaves simple, alternate, deciduous, thin, light green and glabrous above, paler and smooth below, 3-veined at base, 2.50 to 4 inches long, 1 to 2.50 inches wide.

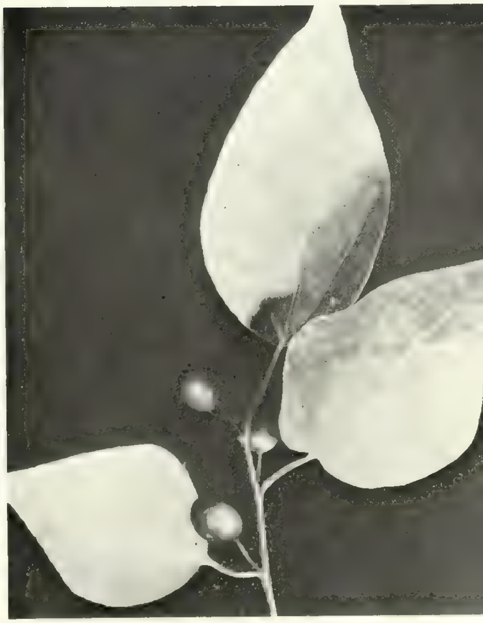
Twigs light green to reddish brown, lustrous.

Flowers small, inconspicuous, greenish, borne as slender glabrous pedicels, male fascicled, female solitary or two together. Spring.

Fruit an orange red to black drupe, 0.25 inch in diameter, flesh thin and dry. Seed sweet, solitary, pale brown, rough. Ripens in late summer and persists through winter.







Sugarberry/*Celtis laevigata* Willd.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Sugarberry is widely distributed on bottomlands except deep swamps. It thrives on various types of soil but is most common on clay soils of broad flats or shallow sloughs within the flood plains of major southern rivers. The species grows in association with a wide variety of hardwoods It is intolerant of shade, but when released, grows rapidly and suppresses species of higher commercial value. In dense, even-aged stands it prunes itself well and produces a straight stem.

The fruits are eaten by many songbirds, upland game birds, and small mammals. It is a preferred fall and winter food of wild turkey. White-tailed deer occasionally eat the leaves and twigs.

Fruit yields are optimum when trees are 30 to 70 years old. Seeds are borne nearly every year with good crops in most years. Late spring frosts sometimes kill the flowers and reduce the seed crop. Seeds are low in crude protein, moderate in phosphorus, and high in calcium.

Seed may be sown in fall or stratified in moist sand at 41°F for 60 to 90 days and sown in spring. The species can also be propagated by cuttings. Small stumps sprout readily, and there is some sprouting from root collars of fire-damaged seedlings and saplings. The bark is thin and easily damaged by fire. A light burn kills reproduction and a heavier burn may kill or seriously damage large trees.

The wood is used to a limited extent for furniture, flooring, crating, fuel, and cooperage. The species is often planted along streets or as a yard tree.

Other common names: sugar hackberry, hackberry, Texas hackberry.

Hackberry/*Celtis occidentalis* L.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Hackberry is principally a bottomland tree, but it grows on many soils and is frequently found on limestone outcrops or limestone soils. Sites with a permanently high water table are unfavorable for hackberry, although periodic flooding apparently is not detrimental.

Hackberry is found in many forest stands but seldom occurs in pine stands. It is intermediate to tolerant of shade, and trees suppressed for a long period are often of poor form. It is drought resistant and in the South is often planted for shade and as a shelter belt.

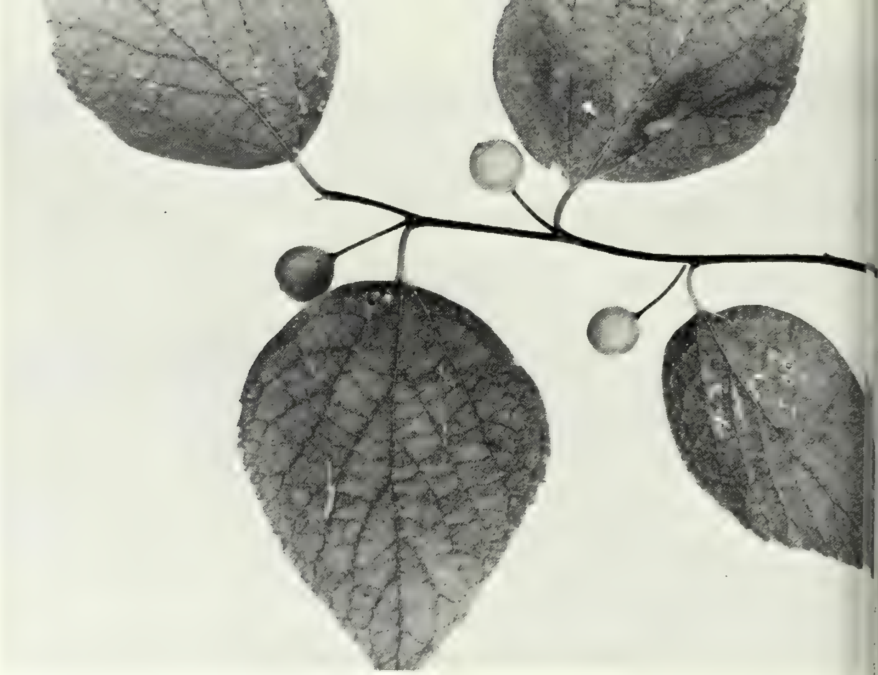
The fruits are eaten by many species of birds and small mammals. They are preferred fall and winter food for turkeys, and a principal food for raccoons. They make up a small part of the diets of pheasants, waterfowl, quail, and ruffed grouse. Squirrels eat the fruits, and to a lesser extent the buds and bark.

Hackberry bears good seed crops in most years. Seeds are exceptionally high in calcium, moderate in nitrogen-free extract, crude protein, and phosphorus, and low in crude fiber. Seed can be sown in fall or stratified in moist sand at 41°F for 60 to 90 days and sown in spring. Hackberry can also be propagated from stem cuttings and by ayering. Sprouts develop from stumps of small trees but rarely from larger trees.

The wood is occasionally used commercially for fuel, furniture, veneer, and agricultural implements.

Hackberry is highly susceptible to fire, which opens the way for wood decay organisms.

Other common names: common hackberry, sugarberry, nettle-tree, false-elm, bastard-elm, beaverwood, rim-ash, one-berry.



Hackberry

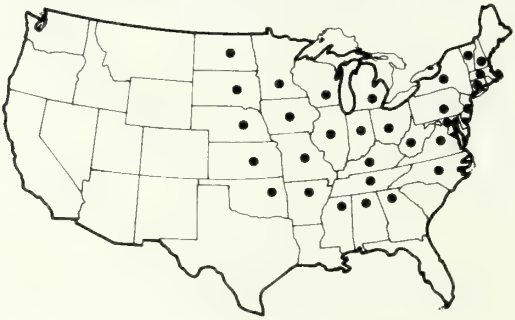
A tree 30 to 50 feet tall and 18 to 24 inches in diameter; its gray bark bears corky warts and ridges.

Leaves simple, alternate, deciduous, coarsely serrate, light green and glabrous above, paler green and pubescent below, blade 2.50 to 4 inches long, 1.50 to 2 inches wide, leaf base inequilateral.

Twigs green to reddish brown, slender, glabrous or pubescent, zigzag.

Flowers small and green; appear with or shortly after leaves; female flowers borne solitary or in pairs; lower flowers usually male only.

Fruit a globose, orange-red drupe, turning dark purple, 0.25 to 0.33 inch in diameter, persistent. Flesh thin, yellow, sweet. Seed bony, light brown, smooth or pitted. September-October.



Fringetree/*Chionanthus virginicus* L.

Phil D. Goodrum
U.S. Fish and Wildlife Service
Nacogdoches, Texas

Fringetree is most abundant in the understory of pine-hardwood forests, especially on moist, acid, sandy loam soils. It reaches best development in semi-open situations but is moderately tolerant of shade and occasionally is found in dense understories. Though its distribution is wide, it is usually a minor part of the total vegetation. It is among the shorter-lived shrubs.

The date-like fruit and seeds are eaten by many birds and mammals ncluding turkey, quail, and deer. Fringetree is preferred browse for deer in the Gulf Coast Plain, but in the Piedmont and mountains it is browsed only lightly. Greatest use is in spring, summer, and fall. The species is moderately intolerant of browsing, and plants often die when more than one-third of the annual growth is removed. The foliage is eaten by cattle.

Observations in Mississippi, Louisiana, and eastern Texas indicate that hot fires will rootkill most specimens but a light fire induces sprouting and helps keep forage available to deer.

Fringetrees are planted throughout the South as ornamentals. The bark has medicinal uses as a diuretic and fever remedy.

Other common names: white fringetree, old man's bear, flowering ash, grandfather-gray-beard.

Fringetree

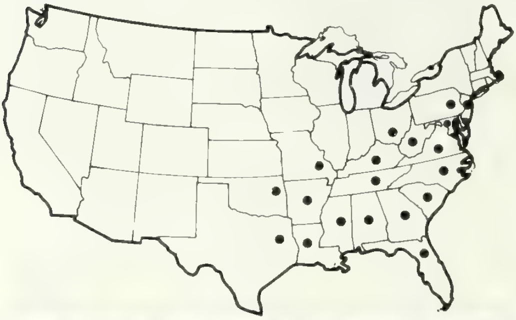
A shrub or small tree up to 35 feet high.

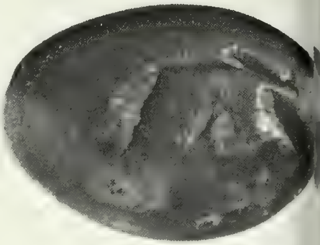
Twigs reddish-brown at tip, stout, pubescent. Leaf scars raised and moderately large; lenticels warty, round, or shield-shaped.

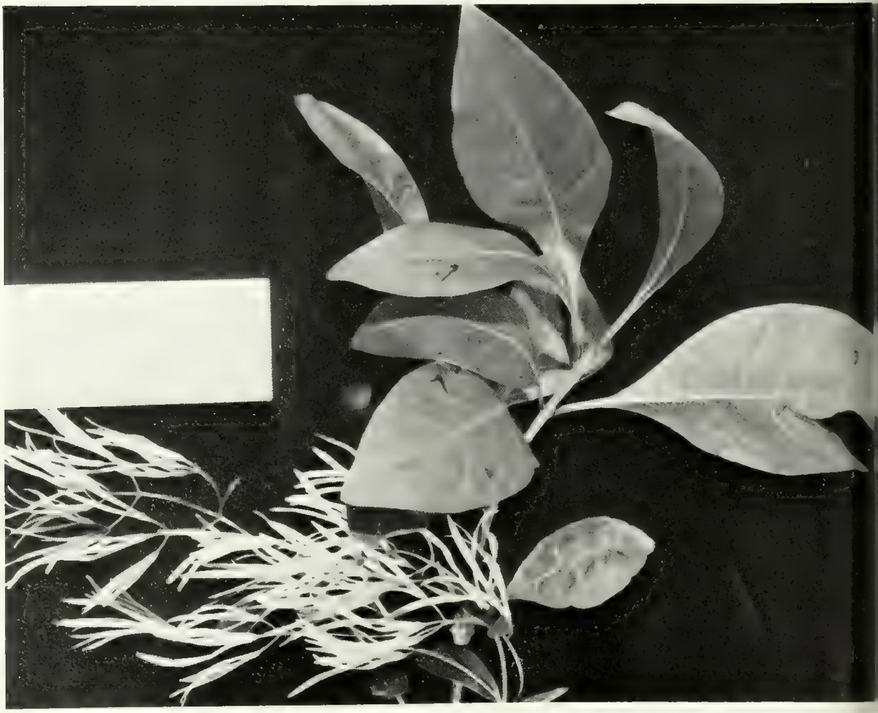
Flowers white and fragrant, borne in delicate drooping panicles 4 to 6 inches long. March to June.

Leaves opposite, deciduous, 4 to 8 inches long, 1 to 4 inches wide. Dark green and glabrous above, paler below with hairs on veins.

Fruit a purple oval drupe 0.50 to 1 inch long, borne in loose clusters, one to three seeds. August to October.







Flowering Dogwood/*Cornus florida* L.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Flowering dogwood is an understory species that is very tolerant of shade and is especially common in young forests and mixed pine-hardwoods. Dogwood is found on a variety of soils ranging from deep moist soils along streambanks to well drained light upland soils, but is usually scarce or absent on poorly drained soils. It grows best on sites having a northern aspect and moist, rich loams with a pH of 6 to 7. A shallow root system makes it vulnerable to prolonged droughts.

Virtually all game species use the fruit. It is a preferred food by wild turkeys, and is readily eaten by white-tailed deer, ruffed grouse and quail, and to a lesser extent by wood ducks. The fruit is eaten by many kinds of songbirds, particularly cardinals, grosbeaks, robins, brown thrashers, and cedar waxwings, and by mammals such as rabbits, foxes, black bears, and chipmunks. Grouse sometimes eat the buds and flowers during spring.

Because of its browse and fruits and its widespread occurrence, dogwood is one of the most important deer food plants. Foliage and twigs are often heavily browsed except in the Gulf Coast areas where use is light to moderate. The browse is most palatable in spring and least, in winter.

Cattle frequently compete with deer and may use up to 50 percent of available browse. Dogwood is also browsed by rabbits.

In east Texas, maximum dry-weight yields of fruit were 1.7 pounds for 11-year-old trees growing in the open and 0.2 pounds for plants growing beneath pine trees. The pulp-seed ratio of fruits usually ranges from 1:0.85 to 1:1.05.

The fruits are low in crude protein and phosphorus but high in calcium. The browse is high in calcium, manganese, and cobalt, but low in crude protein during the winter. The leaves of dogwood may concentrate fluorine.

Dogwood seed germinates in the spring after it has lain on the ground over winter. Freshly gathered seed will germinate following moist storage for 100 to 130 days at 0° to 10°C. Seed stored above 15° will not germinate.

Flowering Dogwood

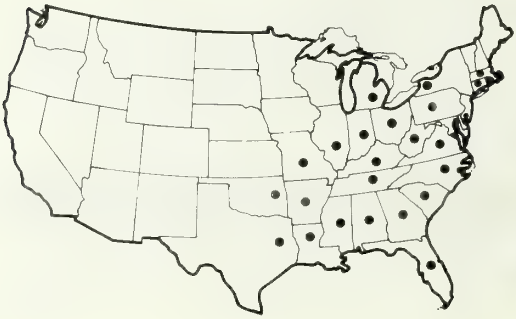
A shrub or small tree up to 40 feet tall.

Leaves simple, opposite, dark green above, light green and glaucous below, often clustered near end of branches. Blades 3 to 5 inches long, 1.50 to 2.50 inches wide.

Twigs green or purple, often with whitish bloom. Buds scaly, outer scales of terminal bud bivalvate. Leaf scar somewhat raised upon the persistent leaf base.

Flower bracts snowy white or, rarely, pink; 1.25 to 2.50 inches long. March to June.

Fruit a bright red, clustered drupe, 0.25 to 0.50 inch long. September to October and persist through early winter.



Dogwood can be propagated by layering and cuttings.

Because the bark is thin, stems are easily killed by fire, but rootstocks send up numerous sprouts that provide succulent and nutritious forage. Plants die if flooded for several weeks.

Its flowers and foliage make dogwood a favorite among gardeners. The wood is used for shuttleblocks in the textile industry and for other specialty products.

Dogwood litter decomposes rapidly, thus making its nutrients readily available.

Other common names: dogwood, arrowwood, boxwood.

Dwarf Huckleberry/*Gaylussacia dumosa* (Andr.) T. & G.

Ralph H. Hughes
Forest Service, USDA
Fort Myers, Florida

Dwarf huckleberry grows best in shaded peaty or sandy soils and is commonly found in flat damp woods that are frequently burned. Like other plants in similar habitats, it is protected from extermination by a network of underground stems that put up new shoots after a fire.

Fire can be used as the main management tool for dwarf huckleberry. Plants flower and fruit vigorously and prolifically if pruned back by fires at regular intervals. On forested ranges managed for quail or wild turkey, huckleberries are most abundant on areas burned at two- or three-year intervals. When burned in winter the plants do not bear fruit the following growing season; however, when burned in July or August the plants bear fruit the following year.

Fruits of dwarf huckleberry are eaten by bobwhite quail, wild turke ruffed grouse, several songbirds, foxes, and squirrels. In one south Georgia study, fruit, including huckleberries, was more than half the food of quail during June and July. A large portion of the huckleberry seeds eaten by quail in summer pass through the digestive system without being crushed. When taken during the winter months the seed are thoroughly pulverized.

On burned areas the leaves and stems are eaten by cattle. Leaves have been found in small quantities in the stomachs of white-tailed deer in Florida.

Dwarf huckleberry is propagated by seeds, layers, or division. Man native species of huckleberry have been collected and planted in gardens.

Blueberries are often mistaken for huckleberries. The latter have 10 one-seeded nutlets; the blueberry is a true berry with many small seeds immersed in the pulpy flesh.

Other common names: bush huckleberry, and gopher-berry.

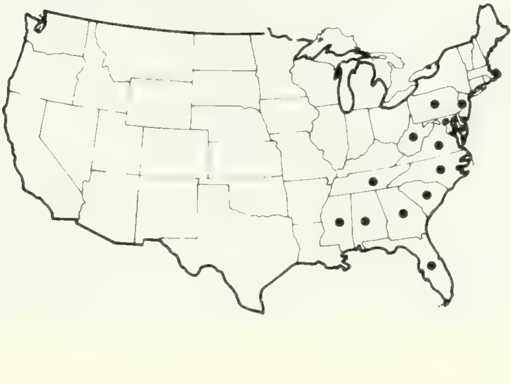
Dwarf Huckleberry

A low shrub not usually over 18 inches tall, with creeping stems and upright branches.

Leaves 0.50 to 2 inches long, deciduous, thick or somewhat leathery, upper surface shining, resinous beneath. New growth glandular hairy.

Flowers white or pinkish, appearing in rather dense racemes before the leaves are fully expanded. April to June.

Fruit blue to black globose berry-like drupe, 0.20 to 0.30 inch in diameter, nutlets one-seeded, 10 per fruit. May and June.



Hollies/***Ilex*** spp.

Hollies are mostly small trees or shrubs. The leaves are simple and alternate and are deciduous on some species, evergreen on others. The plants are usually dioecious. The female flowers tend to be solitary, and the male flowers cluster in the axils. The fruits are berry-like drupes with one stone in each of four to nine cells. At maturity the fruits are red, reddish-orange, black, or, rarely, yellow. For most species the fruit persists through winter.

The fruits are eaten by many kinds of birds and mammals, and foliage of some of the evergreens is an important source of winter food for white-tailed deer.

The fruits are low in crude protein and phosphorus, and high in crude fat and crude fiber.

Dahoon/*Ilex* cassine L.

Ralph H. Hughes
Forest Service, USDA
Fort Myers, Florida

Dahoon is found in swamp margins and low ground, along stream borders and pond edges, in damp acid soils, often beneath closed canopies of southern pines and loblolly bay. It grows naturally farther south than any other native red-fruited holly.

Rootstalks sprout readily after a burn and forage can be increased by cutting tree-like plants. Where regularly killed back by fire or by cutting, dahoon is browsed all year by deer and cattle.

The ripened red fruits are eaten by raccoons, opposums, squirrels deer, and many kinds of birds including bobwhite quail and wild turkey. Fruits ripen in autumn and remain on the tree until spring. The are not edible by man, being emetic and cathartic.

Seeds germinate readily, and specimens may grow a foot or more in one season. Freshly gathered and cleaned seeds germinate in a month when sown in greenhouse flats containing a mixture of sand, soil, and peat.

Dahoon is easily grown from cuttings and may be grafted on *Ilex opaca* stocks. Terminal twigs in good growth are best for cuttings.

The plant is quite variable in fruit production and selection is necessary to get the best types. Selections and hybrids of the species are widely distributed by the nursery trade in the southeastern United States.

The berries are gathered widely during the holiday season. Becau the leaves are not conspicuously spiny dahoon is rarely recognized as a holly.

Other common names: dahoon holly, Christmas berry, yaupon, cassena, Alabama dahoon.

Dahoon

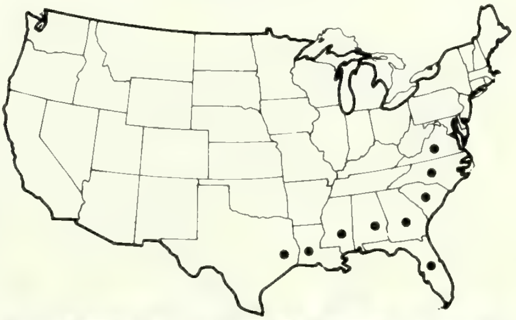
A shrub or small tree up to 25 feet tall.

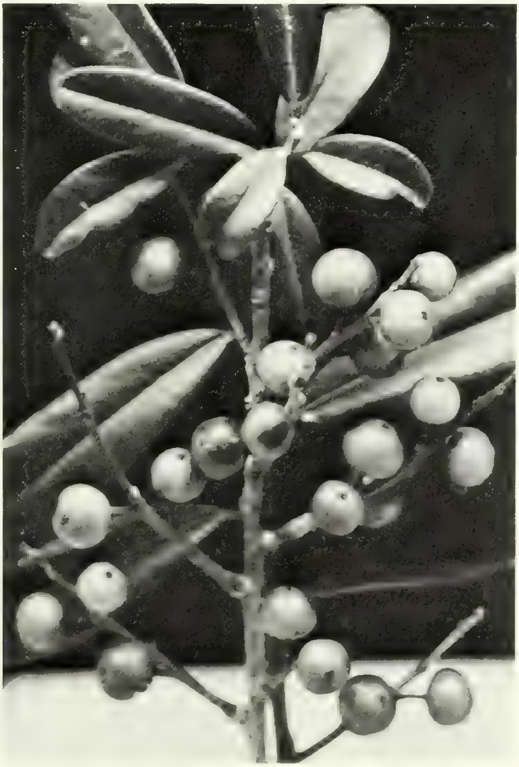
Leaves 1.30 to 4 inches long, leathery, with down-like hairs beneath. Evergreen.

Stem slender, finely hairy the first 2 or 3 years. Leaf scar crescent shaped, bundle scar solitary, pith smooth and continuous.

Flowers numerous, small, white in umbel-like clusters, usually on new growth. May to June.

Fruit bright to dull red or yellow, 0.20 to 0.75 inch in diameter, four nutlets, each about 0.16 inch, persists until spring.





Large Gallberry

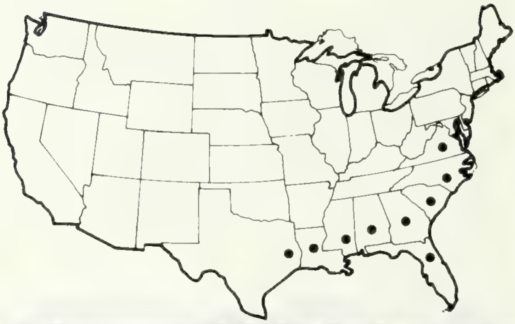
A shrub usually less than 10 feet high.

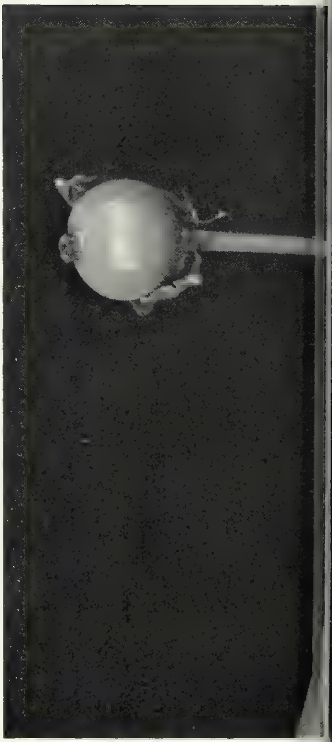
Leaves 1.50 to 3 inches long, glaucous beneath, tips acute and short, sharp spines are sparingly borne on leaf edge from about midpoint to tip, evergreen.

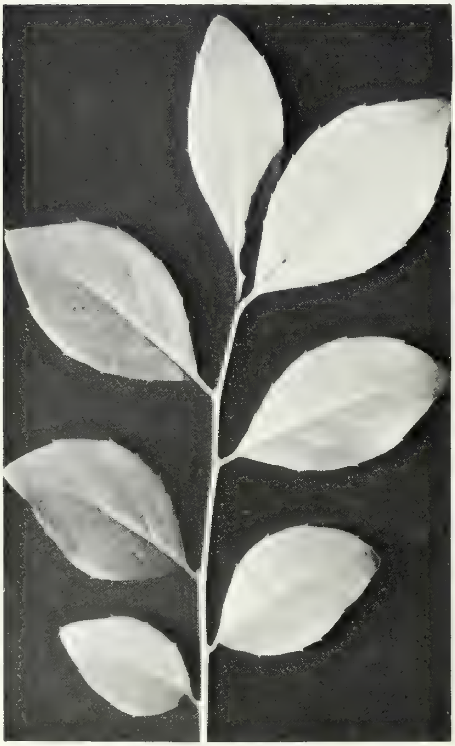
Stem slender, green to gray, smooth or slightly hairy.

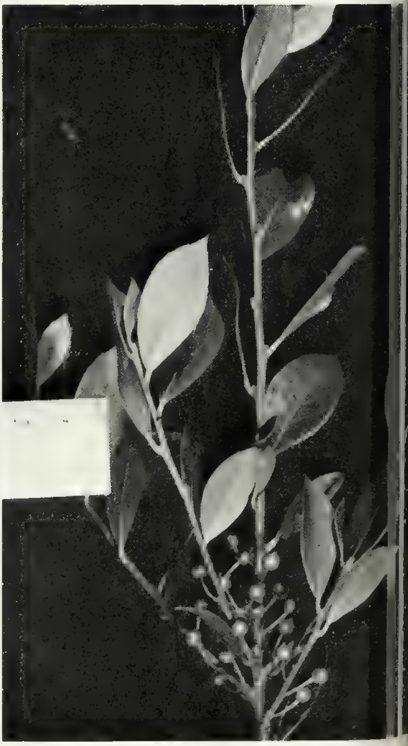
Flowers small and white. April to May.

Fruit shiny, black, smooth, soft, and pulpy. Ripens in fall.









Large Gallberry/*Ilex coriacea* (Pursh) Chapm.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Large gallberry grows in the shade or in the open along streams and swamps as well as on upland sites that have sandy, acid soils.

Game animals and birds, including deer and quail, eat the fruits, but the yields are generally less than those of other hollies. Large gallberry is one of the most preferred deer browse plants within its range and furnishes palatable forage throughout the year. Forage yields are high even where browsing is heavy. Unless the stems are killed back regularly by fire or other means, most of the foliage grows beyond reach of deer. Rootstocks sprout readily after a burn.

The plant closely resembles common gallberry (*I. glabra* L.) but can be distinguished by the spine on its leaf margins, glaucous undersurface of leaves, and a generally larger growth.

Other common names: shining inkberry, baygall-bush, tall inkberry holly, sweet gallberry.

***Possumhaw*/*Ilex decidua* Walt.**

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Possumhaw occurs along streams or ponds. The persistent orange to scarlet fruits make the plants conspicuous during fall and winter.

Deer and cattle eat the leaves and tender twigs in early spring. The fruit is taken in winter by many birds, including wild turkey and quail, and by deer. The plants often interfere with timber reproduction, but can be controlled by burning or slashing stems or by spraying with 2,4,5-T in diesel fuel.[1] Slashing or burning is preferable because the resulting sprouts are readily eaten by deer.

Other common names: swamp holly, deciduous holly, bearberry, winterberry, Curtiss possumhaw.

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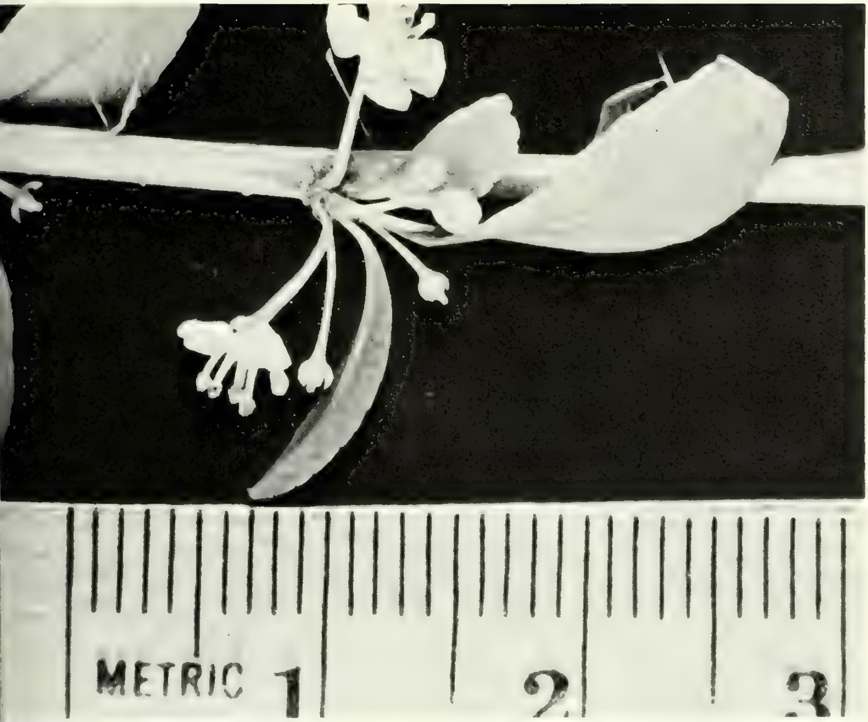
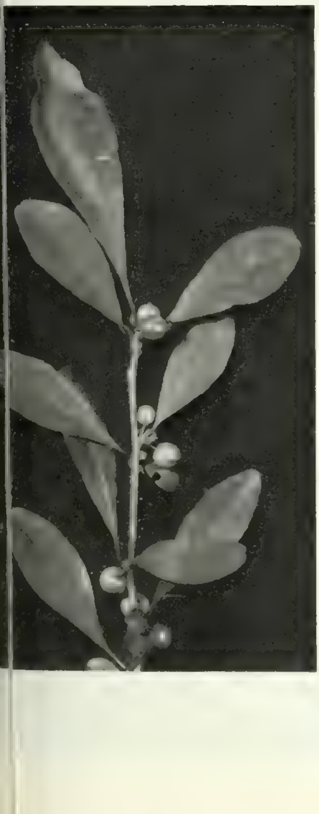
[1] This paper reports research involving herbicides. It does not contain recommendations for their use nor does it imply that the uses discusse here have been registered. All uses of herbicides must be registered by appropriate State or Federal agencies before they can be recommended.





Possumhaw

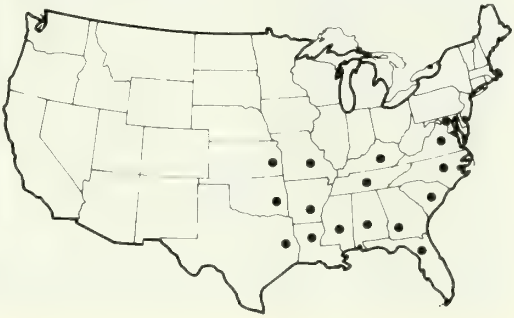
A shrub or small tree up to 30 feet tall.

Leaves 1.25 to 3 inches long, 0.50 to 1.50 inches wide, alternate in crowded groups at end of short branchlets, thick and firm, deciduous, smooth on upper surface, lower surface sometimes pubescent on ribs.

Twigs have gray bark with warty-appearing lenticels; buds small with two scales; leaf scars small, half circular or occasionally narrow slits; one bundle scar.

Flowers small, whitish. March to May.

Fruit orange to scarlet, 0.30 inch in diameter. Ripens in early fall, persists through winter.



Gallberry

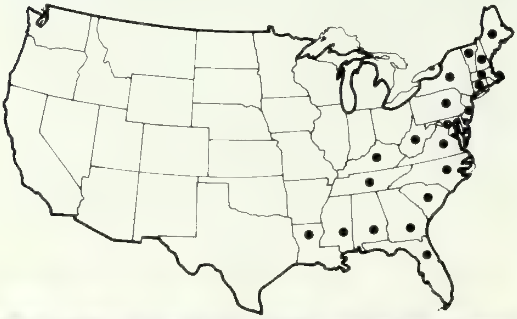
A stoloniferous shrub, forming dense clumps up to 6 or 10 feet in height.

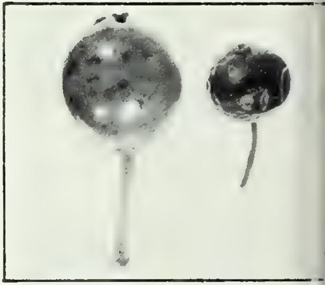
Leaves leathery, persistent, lustrous dark green above, lighter with tiny dots beneath, 1.20 to 1.80 inches long and 0.60 to 0.80 inch wide.

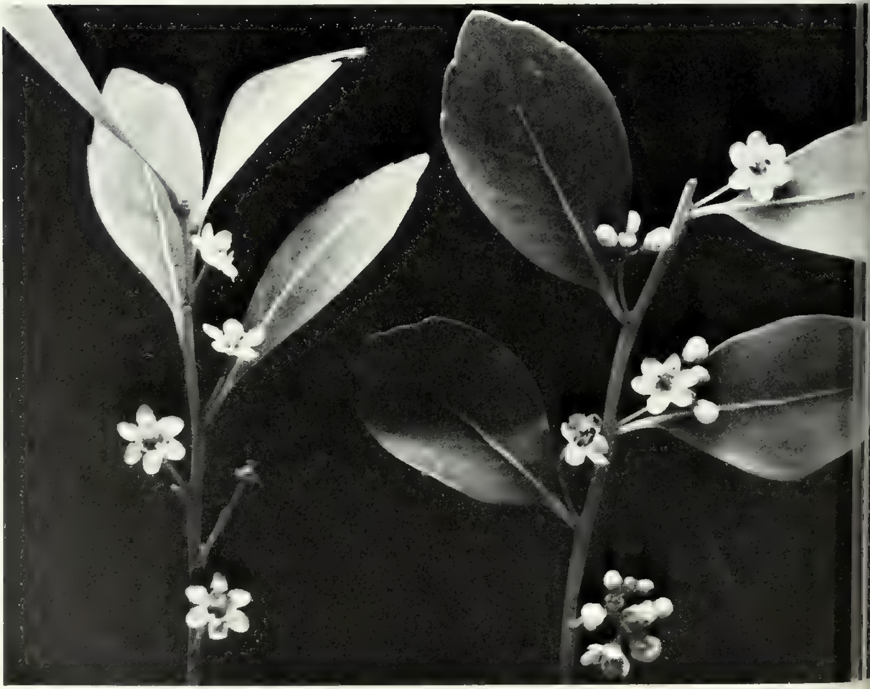
Flowers white, male flowers several, on long peduncles; female flowers solitary on new growth. February to July.

Fruit black, shiny, smooth, up to 0.30 inch in diameter, borne individually or in small clusters, persistent. July and August.

Seeds three to nine, usually six, black, thin, flat, smooth. About 0.14 inch in diameter and 0.03 inch thick.







***Gallberry*/*Ilex glabra* (L.) Gray**

Ralph H. Hughes
Forest Service, USDA
Fort Myers, Florida

Gallberry is most abundant in the piney flatwoods of southeastern Georgia and central and northeastern Florida. In the upper parts of its natural range where soil reaction is weakly acid, gallberry is conspicuously absent, but it is present in wet, sandy, and peaty places where soils are highly acid. It grows poorly in soils with a high lime content.

Because of its stoloniferous habit, gallberry often grows in thickets and excludes many favorable forage plants, thereby reducing the grazing capacity for domestic livestock. The thickets are also severe obstacles to naval stores operations and greatly increase the danger of woods fires.

Gallberry thrives with frequent winter burning. Fire kills back top growth for a few months, but new sprouts soon furnish as many stems as were originally present or more. While top growth may be checked by annual burning, particularly by summer burning, seasonal patterns of carbohydrate level in roots and stems are unaffected by season of burning. Recovery of carbohydrates apparently occurs within one year regardless of time of year burned.

Even without burning, gallberry persists and oftentimes increases beneath canopies of pine. In the flatwoods of Georgia, foliage cover of gallberry increased threefold during 20 years continuous protection from fire. In one series of plots not burned in 30 years gallberry now is the dominant understory shrub.

Natural seedlings are rare and virtually all new growth originates from sprouts.

Fruits, each containing about six nutlets, remain on the bush throughout the winter, but begin falling when new growth starts.

The fruit has been recovered from many species of birds including mourning dove, bobwhite quail, and wild turkey, and from white-tailed deer, marsh rabbits, and bears. Songbirds such as the hermit thrush and mockingbird have been observed eating the fruit. Livestock eat the foliage sparingly; deer in central Florida eat the leaves and berries during the fall and winter.

In the coastal flatwoods, where gallberry covers many thousands o acres, gallberry fruits and seeds are eaten by quail during the early-spring. The seeds are nearly always ground up, that is, rarely do they pass through the digestive tract without being crushed.

Good seed crops seem to appear annually; however, an individual plant or clump may bear heavily one year and be barren the next. Plan killed back by fire or cut off near the ground bear neither flowers nor fruit until the second year.

Good germination may be obtained immediately after collection by cleaning and sowing seed in a moist, fungus-free medium at a temperature of 60°F until the seeds sprout.

Gallberry is often planted as specimen shrubs and hedges because of its shining, persistent foliage and black, glistening fruits.

Gallberry flowers are the source of fine honey in the Georgia-Florida pineywoods.

Other common names: inkberry, bitter gallberry, winterberry.

***Myrtle Dahoon*/*Ilex myrtifolia* Walt.**

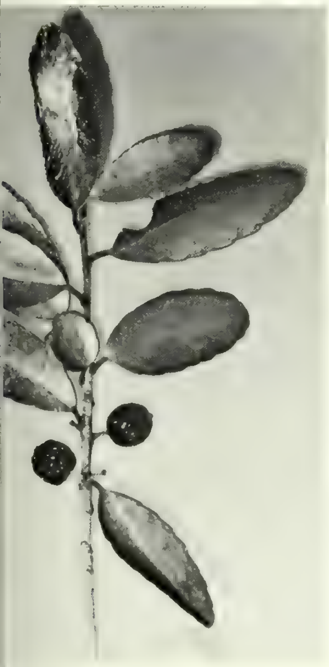
Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Myrtle dahoon grows in wet acid soil around cypress ponds and swamps and in pine barrens.

Fruits are eaten by small mammals and birds.

The plants are often used as ornamentals and can be grown readily from seed. It often hybridizes with dahoon.

Other common names: small-leaf dahoon, myrtle holly, cypress holly, myrtle-leaved holly, dahoon.



Myrtle Dahoon

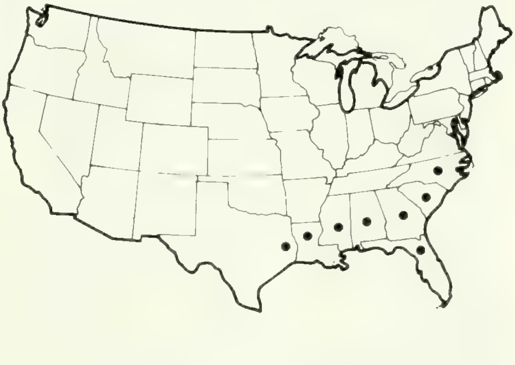
A small, evergreen shrub with numerous crooked rigid stems, or a small tree up to 23 feet tall.

Leaves leathery, 0.40 to 1.50 inches long, 0.20 to 0.33 inch wide, entire margin, upper surface dark green and glabrous, lower surface paler and glabrous.

Twigs slender, rigid, smooth, pale, puberulent at first, glabrate later.

Flowers borne on new growth, small, inconspicuous, petals white. May.

Fruit 0.25 inch diameter, red to orange and yellow, flesh thin and yellow, four nutlets, ribbed. Matures in late fall, persistent over winter.



American Holly/*Ilex opaca* Ait.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

American holly grows in well-drained rich woods, in hammocks, and along banks of streams.

The fruits are eaten by many species of songbirds, mourning dove, wild turkey, quail, small mammals, and white-tailed deer. The foliage is sometimes browsed by cattle.

This tree is planted widely as an ornamental. The bright colored fruit and attractive evergreen foliage are used as Christmas decoration

Holly seed may be sown broadcast or in drills in the fall or stratified over winter and sown in the spring. Recommendations for American holly also include: stratification for 30 days at 75°F to 80°F before sowing; burying seeds mixed with sand or peat and sowing ther after the second winter; sowing berries and covering them with a heav mulch until the spring of the second year. Holly plants should be transplanted only when dormant. Propagation by cuttings, layering, or grafting is also practiced.

The close-grained, shock-resistant wood is used for cabinets, inter finish, novelties, handles, fixtures, and scientific instruments.

Other common names: holly, white holly.

American Holly

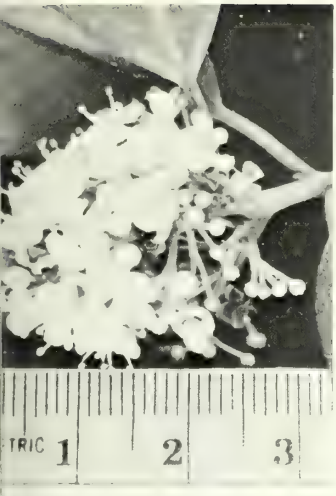
An evergreen tree to 70 feet tall, with short crooked, branches and a rounded or pyramidal crown.

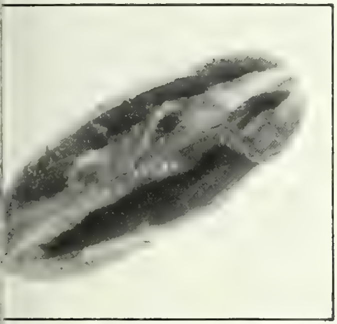
Leaves simple, alternate, persistent, oval with stiff, wavy margin, with sharp, stiff, flat spines; upper surface dark green lustrous or dull, paler and glabrous to puberulous beneath, 2 to 4 inches long, 1 to 1.50 inches wide.

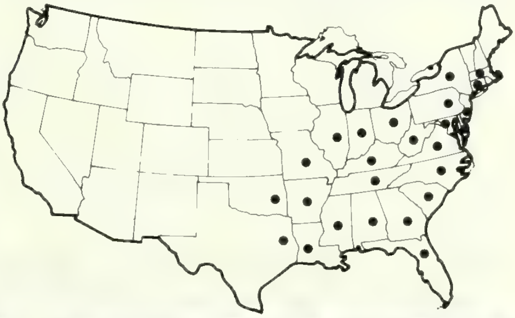
Twigs stout, green to light brown or gray, glabrouse or puberulous.

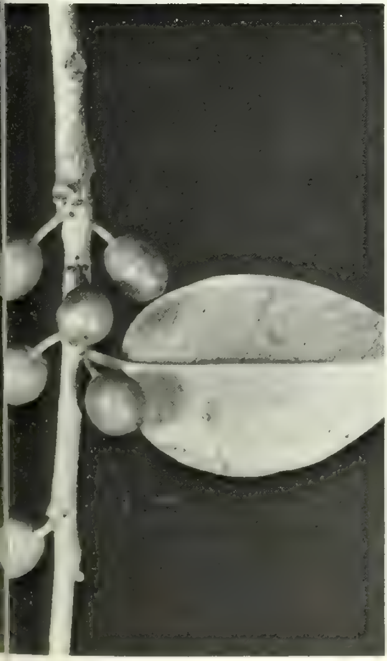
Flowers dioecious; short stalked clusters, staminate in three- to nine-flowered cymes, small, white, petals four to six. April to June.

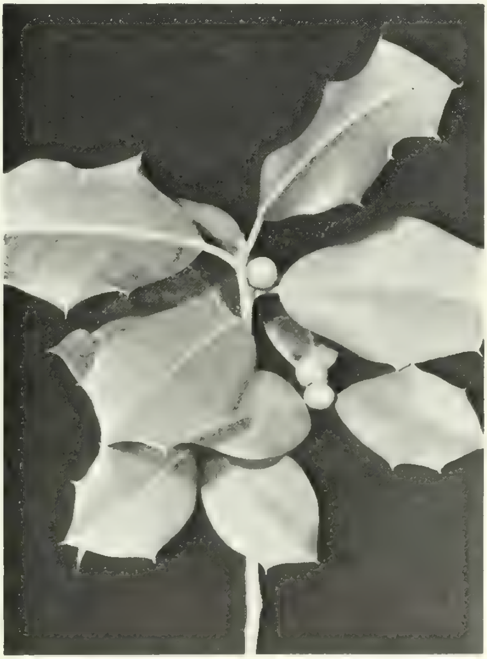
Fruit spherical or ellipsoid, drupes mostly red, more rarely yellow or orange, 0.25 to 0.50 inch long; nutlets, ribbed. November and December.











***Yaupon*/*Ilex vomitoria* Ait.**

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Yaupon grows in moist sandy soils that have permeable subsoils. It is most abundant in the Coastal Plain forests of Louisiana, Texas, and Arkansas. It begins growth in mid-March, when many new shoots form and elongate rapidly. During dry weather twig growth practically ceases, but the plants put on a new flush when soil moisture again becomes favorable. With enough rain, plants continue growing to mid-October.

Yaupon provides fruit for deer, turkey, quail, squirrel, raccoon, and many songbirds. For deer, yaupon leaves are a reliable source of green forage in late winter, and are of special significance because they contain sufficient protein for maintenance of deer.

When browsed heavily, yaupon tends to hedge, and the short stiff branches protect enough leaves inside the crown to keep the plant alive. Thus, the species survives on overstocked range, although the plants may develop grotesque shapes.

Yaupon grows well beneath trees but best in the open. Up to 150 pounds per acre of yaupon browse (green weight) have been grown beneath pine stands in east Texas, but plants in the open have produce 5 to 57 times more than plants of the same age beneath trees.

Yaupon plants growing in the open tend to bear high fruit yields in alternate years. In a study near Nacogdoches, Texas the ratio of fruit yields between open- and woods-growth plants was found to be 19:1. At age 11, fruit yields for plants in the open averaged nearly 5 pounds (dry weight).

Fruits are low in crude protein, phosphorus, and calcium, and higl in fat and crude fiber.

Yaupon competes with forage grasses for moisture and is regarde as a weed species by cattle growers in central Texas. It offers little hindrance to tree growth, and is not considered a pest in forest manag ment.

Summer burns or a series of hot winter fires will kill yaupon. However, infrequent winter burns of moderate intensity may serve a useful purpose in keeping new growth near the ground and available to deer. Fruit yields will be at a minimum in the year following a burn.

Yaupon

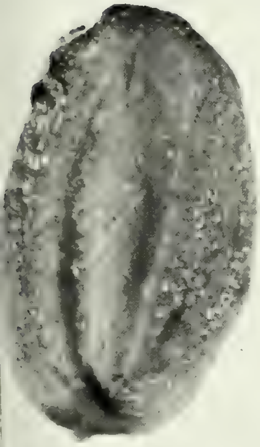
Thicket-forming shrub up to 25 feet tall.

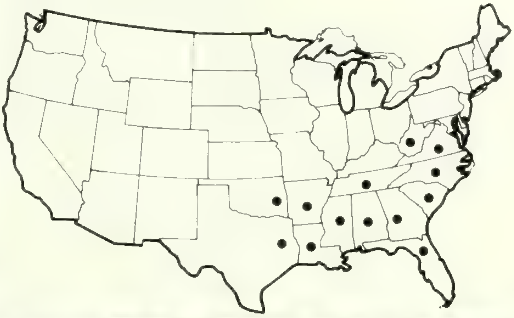
Leaves evergreen, leathery, dark green and lustrous above, pale below; 0.5 to 2 inches long, persistent for two to three years.

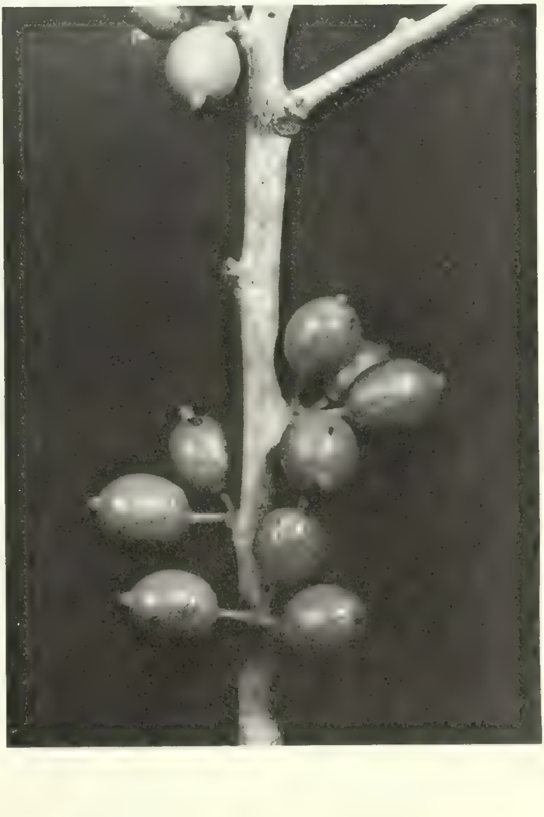
Stem has stiff divergent branches, smooth whitish-gray bark.

Flowers small and white in nearly sessile clusters on branches of previous year; some monoecious, others dioecious. April.

Fruit a bright red drupe 0.25 inch in diameter, four pale amber seeds 0.15 inch long. October, persists through winter.







Although yaupon may be difficult to grow from seed, good results were obtained with a schedule developed at the Stephen F. Austin Experimental Forest near Nacogdoches, Texas. Mature seeds were collected in the fall, stored over winter in moist sand at about 40°F, sowed in nursery beds the following March, and then kept covered for a year with a thin layer of soil and 2 to 3 inches of pine straw. In the spring of the second year the straw was removed and seeds germinated Seedlings remained in the well-watered nursery until the following February when they were transplanted by dibble into an old field that had been disked the previous month. Even though the annual rainfall was only 50 percent of normal, 78 percent of the seedlings were alive at the end of the first year.

Propagation by cuttings is inconsistent. In a three-year study under greenhouse conditions at the Stephen F. Austin Experimental Forest, an average of 14 percent of stems rooted when placed in a 3:1 sand-peat mixture and watered by an intermittent spray for 13 weeks. The highest rooting percentage for any one collection was 53 percent from stems taken in May.

Yaupon is also useful as an ornamental. With pruning, it forms an attractive hedge for the yard or a roadside shrub for highway beautification. Its lustrous evergreen leaves are pleasant to see in winter. The shiny red berries are especially pretty and often are used with Christma greenery.

Other common names: Cassena, Christmas-berry, evergreen holly.

Red Mulberry/*Morus rubra* L.

Dwight M. Moore
Arkansas Polytechnic College
Monticello, Arkansas

William P. Thomas
Forest Service, USDA
Gainesville, Georgia

Red mulberry usually occurs on rather moist sites at elevations below 2,000 feet. Seeds are carried great distances by birds and mammals, so trees might appear on any site which is not too dry. The species occurs as a minor component of both hardwood and coniferous stands within its site range, but is more noticeable as a lone tree near streams and in other moist places. It occurs as a secondary species in succession and is seldom found among first invaders. It is relatively intolerant to fire. Red mulberry appears to be decreasing over much of its range, possibly because of a bacterial disease.

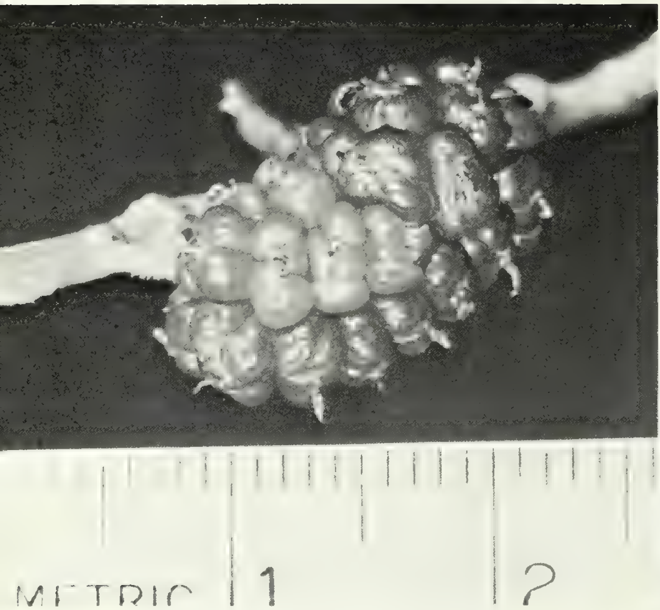
Many songbirds feed heavily on red mulberry fruit when it is available in the spring. Its usefulness as a bird food, however, is limited mainly by its short period of availability and its season of occurrence. Fruits are relished by squirrels, are a favorite food of grouse, and are also eaten by quail, by wild turkey to a limited extent, and by small mammals such as opossums and raccoons. The foliage is browsed by deer, mostly during spring and summer, and rabbits feed on the bark in the winter.

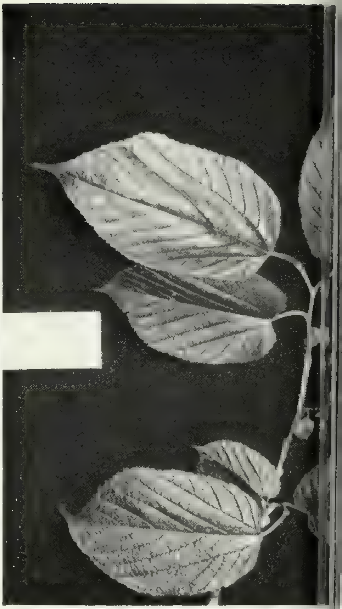
The optimum seed-bearing age is 30 to 85 years, and the maximum 125 years. Late frosts seldom damage flowers since flowers appear after or with the leaves. Excessively rainy seasons at the time of flowering may prevent pollination; otherwise, a good crop of fruit may be expected every year.

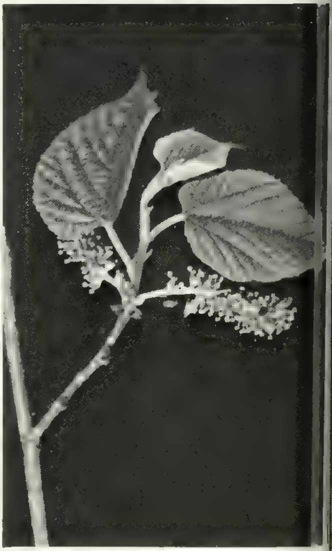
The species is most easily reproduced by sowing seed. Seeds mixed with sand or sawdust may be sown broadcast or in drills during the fall. Stratified seed or seed soaked in water for one week may be sown in the spring and covered with one-fourth inch of soil. Germination is generally poor if seeds are not stratified.

The sweet fruits of red mulberry are palatable to humans. Fruits are eaten directly or made into jelly, jams, pies, and drinks.

The wood is light-weight but durable, and is used for fence posts, barrels, boat building, and farm tools.







Red Mulberry

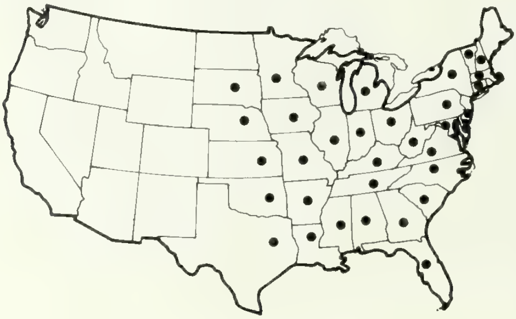
A tree up to 70 feet tall.

Leaves deciduous, simple, alternate, 3 to 9 inches long, three to seven lobed or unlobed, doubly serrate, rough and glabrous above, soft pubescent beneath.

Twigs glabrous, yellowish tan to bluish gray; pith soft, continuous, and white; inner bark turns orange when outer bark scraped away; bud scales orange-tan with dark edges; leaf scars half round or flat oval or circular; many bundle scars in one cluster.

Flowers form with leaves in spring, male spikes cylindric, female spikes cylindric and sessile. March and April.

Fruit an aggregate of small drupes, 0.75 to 1.25 inches long, dark purple or red, resembling a blackberry, juicy. April to June.



Southern Bayberry*/Myrica cerifera* L.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Southern bayberry grows in thickets, woods, swamps, sandy areas, and low, acid prairies.

The fruit is eaten by many kinds of songbirds, bobwhite quail, wild turkey, and by foxes. It is the main food of tree swallows when these birds winter in Florida and the Gulf area. The fruits, twigs, and foliage are eaten sparingly by deer. Heavy browsing by deer is considered by many biologists as an indicator of overpopulation.

The fruits are very high in crude fat content, high in crude fiber, and low in crude protein and phosphorus. The fruit coat is extremely hard and will often pass through the animal undigested, except for the waxy covering which is low in nutritive value. Fruits are widely dispersed by birds. The fruits are not generally considered preferred food, but their persistence makes them a highly regarded emergency item during late winter after more desirable foods are no longer available.

Plants survive burning by resprouting vigorously from the root collar.

Plants can be transplanted when young, but propagation is best accomplished by seeding in moist, silty, acid sand. Best results follow stratification. Propagation by layering is also possible.

The species is planted as an ornamental. Candles were formerly made from the wax extracted by boiling the berries. The bark and leaves reportedly have some medicinal value.

Other common names: bayberry, candle-berry, waxmyrtle, southern waxmyrtle.

Southern Bayberry

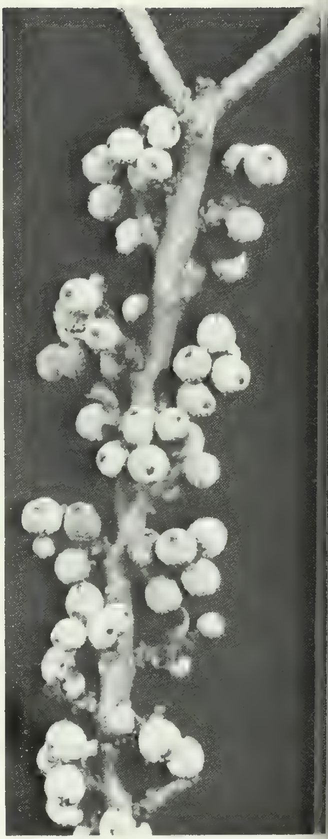
A shrub or small tree up to 40 feet tall.

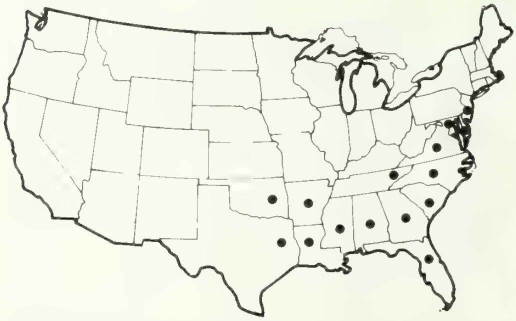
Leaves simple, alternate, persistent, 1.50 to 5 inches long, 0.25 to 0.75 inch wide, margin entire or coarsely serrate above the midpoint, shining above, resinous with orange-colored glands beneath, aromatic when crushed.

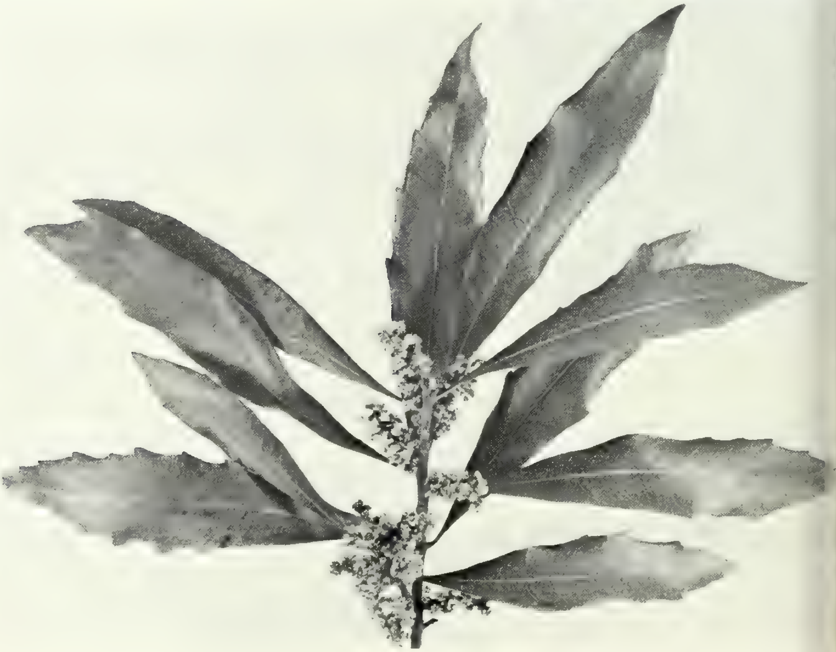
Twigs reddish brown to gray, young parts have deciduous orange-colored glands, young branchlets waxy, glabrous.

Flowers dioecious, male, cylindric, 0.25 to 0.75 inch long; female catkins, short, ovoid. March to April.

Fruit a glabrous, persistent drupe, 0.12 inch diameter, globose, light green, covered with bluish-white wax; seed pale, minute, solitary. September to October.







Northern Bayberry*/Myrica pensylvanica* Loisel

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

This species grows in sandy, boggy soils in the Coastal Plain.

The seeds are eaten by many kinds of birds, particularly by the ruffed-grouse and bobwhite quail.

The fruit is high in fat content and is widely known as a source of wax that is obtained by boiling the fruit in water. The wax is also used for manufacture of soap. Leaves and berries are sometimes used in flavoring soups and stews.

Other common names: bayberry, candle-berry, wax berry, tallow bayberry, bay berry waxmyrtle, small wax berry, candle tree, tallow-tree.

Northern Bayberry

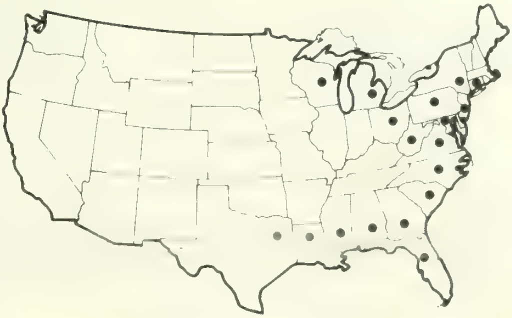
A stout, stiffly branched shrub up to 9 feet tall.

Leaves half evergreen, alternate, 2 to 4 inches long, 0.50 to 1.50 inches wide, entire margin, dark green and semi-lustrous above, glabrous or finely pubescent along veins, lower surface pale and dull green.

Twigs gray, stout, glabrous, glandular-scaly.

Flowers dioecious, male, cylindric, 0.25 to 0.75 inch long; female short, oblong, smaller than male. May to July.

Fruit a persistent, drupe 0.25 inch diameter, waxy-glandular, white, resinous, in crowded clusters, young fruit densely pubescent. September and October.



Water Tupelo/*Nyssa aquatica* L.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Water tupelo grows in swamps, alluvial soil, low wet flats or sloughs, and small ponds, and is rarely higher than 5 feet above the average level of streams. It is associated with many moist-site hardwoods. It may stagnate in crowded even-aged stands but will generally respond to release.

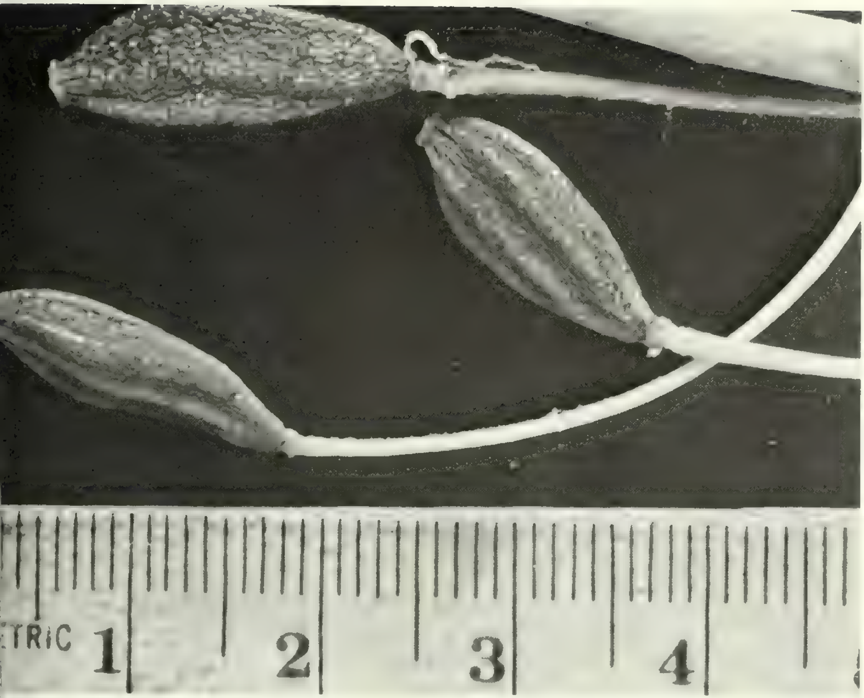
The fruit is eaten by wood ducks, several other kinds of birds, an by squirrels, raccoons, and deer. The flowers have some value as bee food. Deer feed on the foliage and sprouting twigs.

Seed production begins when trees are about 30 years old or about 8 inches diameter at breast height. A heavy crop is produced nearly every year. Untreated seed can be sown in fall, but seed sown in spring should be stratified at 30° to 50°F in moist sand for 60 to 9 days. Water tupelo requires full light for satisfactory germination and seedling development.

Water tupelo is damaged by fire, which facilitates the entrance of rot. Foliage is commonly stripped by forest tent caterpillars; such injur prevents fruiting.

The wood is made into boxes, woodenware, and fruit crates. The light spongy roots can be made into net floats and corks, and are commonly used by duck decoy carvers.

Other common names: cotton-gum, sour-gum, tupelo, swamp tupelo, tupelo-gum, bay poplar.



Water Tupelo

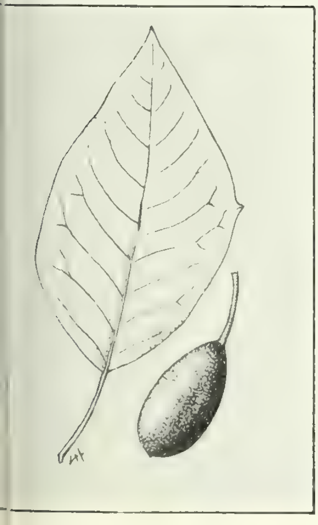
A large tree with swollen base, up to 100 feet tall and 3 to 4 feet in diameter at breast height.

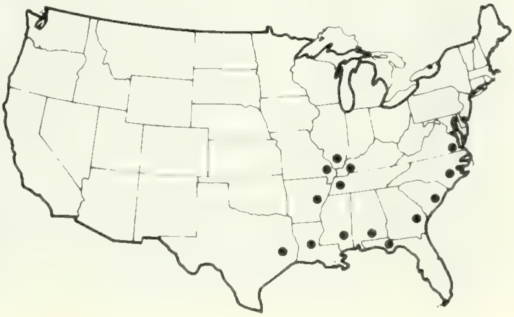
Leaves oblong, simple, alternate, deciduous; entire margin, dark lustrous green and glabrous above, paler and pubescent beneath, 5 to 10 inches long, 2 to 4 inches wide.

Twigs dark, red, stout, tomentose, pithy.

Flowers form before or after leaves; male in clusters, female solitary. March to April.

Fruit a drupe 1 inch long, oblong, dark purple, drooping penducles 3 to 4 inches long; stone rounded, brown or white. September and October.





Black Tupelo

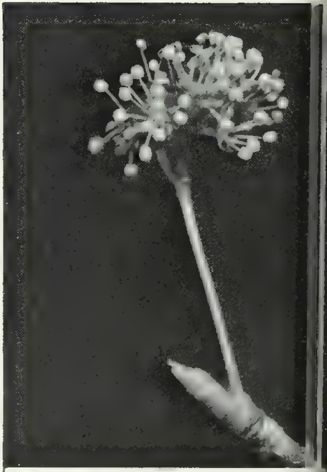
A tree up to 120 feet tall and 4 feet in diameter at breast height.

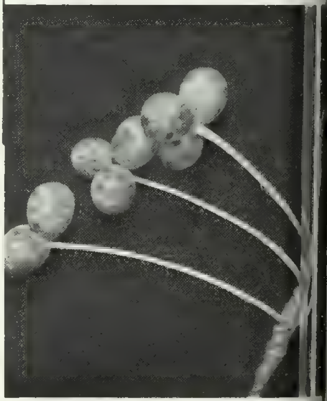
Leaves simple, alternate, deciduous, entire, or with a few coarse teeth, 2 to 4 inches long, 1 to 3 inches wide, thick, firm, lustrous green above, pale and hairy below, frequently with short abrupt tip.

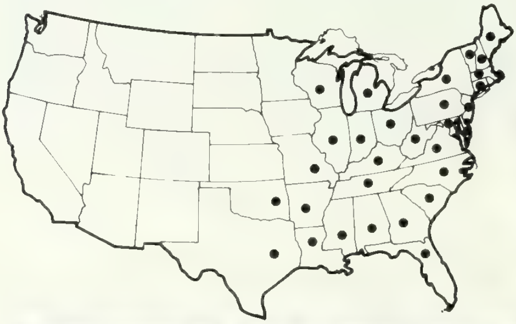
Twigs moderately stout, reddish brown, zigzag appearance, terminal bud ovuid 0.25 inch long, covered with several overlapping reddish brown scales, half round leaf scars, three conspicuous bundle scars.

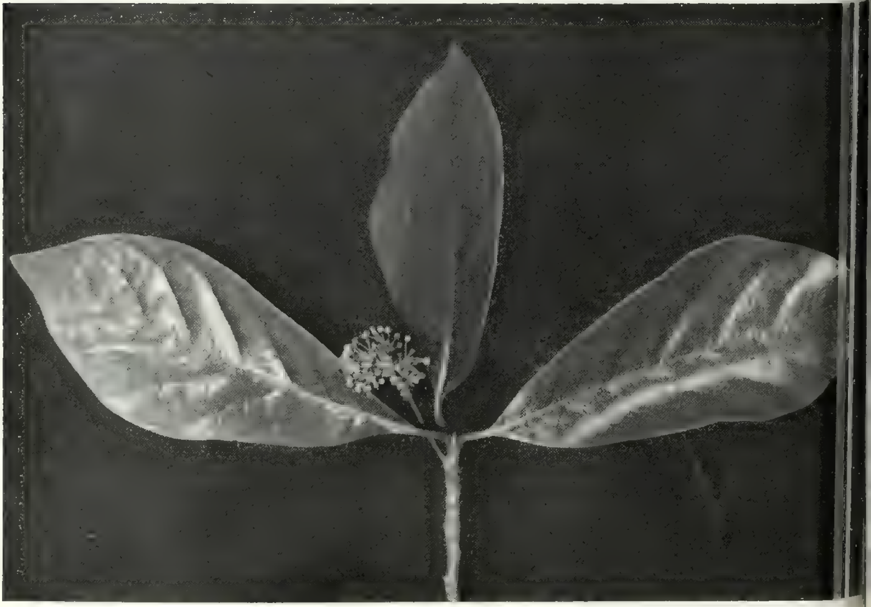
Flowers in axillary clusters, perfect and imperfect. April to June.

Fruit a bluish black, glaucous drupe, 0.25 to 0.50 inch long, usually three to five to a stalk, stone indistinctly ribbed. September and October.









Black Tupelo/*Nyssa sylvatica* var. *sylvatica* Marsh.

Swamp Tupelo/*Nyssa sylvatica* var. *biflora* (Walt.) Sarg.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Black tupelo grows in the uplands and in alluvial bottoms. Best development in the southeastern United States is on the lower slopes and terraces. Swamp tupelo is limited to the Coastal Plain swamps and estuaries; it develops best in the coves and swamps of the Southeast.

Black tupelo does not dominate any major forest type, but it is a component of many hardwood and pine types. Swamp tupelo is of major importance on moist-sites of the lower Coastal Plain.

The fruits of both varieties are eaten by numerous birds, such as quail, wood duck, robin, mockingbird, brown thrasher, thrushes, flicker, and starling, and by several mammals such as white-tailed deer, black-bear, fox, beaver, opposum, raccoon and squirrels. The fruits are considered staple food for wild turkey, although the seeds are often voided whole. Fruits are high in crude fat and fiber, low in crude protein and moderate to high in phosphorus and calcium. The young trees and sprouts are relished by white-tailed deer, but the older plants are of intermediate palatability.

Both varieties require full sunlight for optimum early growth. However, black tupelo will tolerate more overhead competition than swamp tupelo and is usually found mixed with other species but rarely attains dominance except in mountains. Swamp tupelo often develops in even-aged stands but does not assert dominance and will stagnate if heavily stocked.

Untreated seed can be sown in the fall but spring-sown seed should be stratified at 30° to 50°F in moist sand for 60 to 90 days.

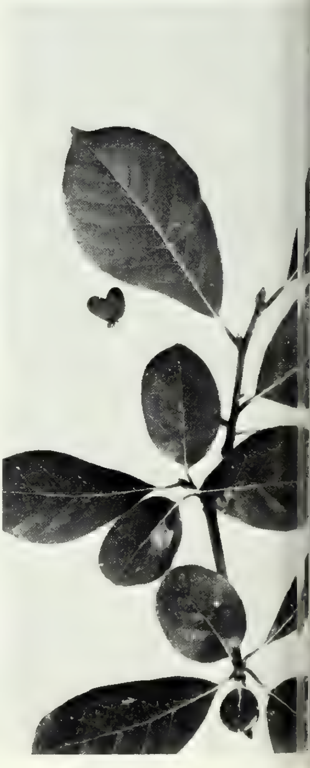
Both varieties suffer from fire. Black tupelo is more often affected by fire because it grows on drier sites; however, a fire may cause severe mortality and timber degrade in swamp tupelo during dry years. The sprouts following fire are highly palatable and nutritious to deer.

Both varieities may be planted as ornamentals. The wood is used for veneer, plywood, and several wood products.

Other common names for water tupelo: blackgum, swamp black tupelo, swamp blackgum.

Other common names for black tupelo: blackgum, pepperidge, sour-gum, tupelo, tupelo-gum, swamp hornbeam, yellow gum.

Swamp Tupelo



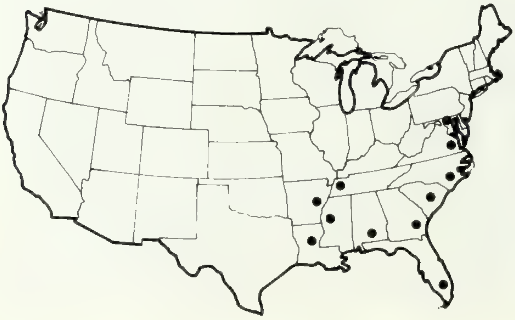
A tree up to 100 feet tall and 4 feet in diameter at breast height, base of trunk swollen.

Leaves simple, alternate, narrow, obtuse, lustrous above, 2 to 5 inches long, 1 to 3 inches wide, broad.

Twigs stout, reddish brown, half-round leaf scars, three bundle scars.

Flowers axillary clusters, perfect and imperfect. April to June.

Fruit a blue to black drupe, 0.33 to 0.50 inch long, stones prominently ribbed, generally two to a stalk. September and October.



***Redbay*/*Persea borbonia* (L.) Spreng.**

Phil D. Goodrum
U.S. Fish and Wildlife Service
Nacogdoches, Texas

Redbay occurs scattered or in thickets along margins of streams, in swamps and hammocks, and occasionally as an understory species in the uplands. It grows well either in deep shade or in the open, and in both young and old forest stands.

The fruit is eaten by at least two species of songbirds and by wild turkey. In the longleaf pine belt, redbay seed may form a sizeable portion of bobwhite quail diet during fall and winter.

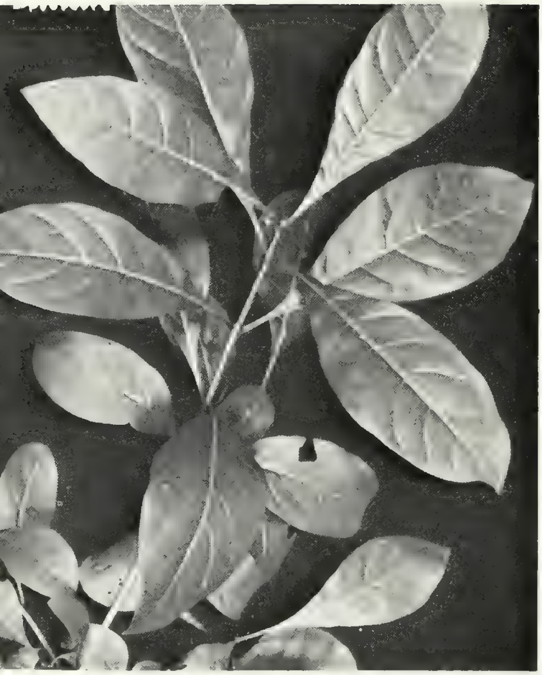
Redbay is of intermediate palatability to deer. At low herd densities it is eaten sparingly, but with heavy stocking current growth is usually browsed closely. Old growth is taken occasionally.

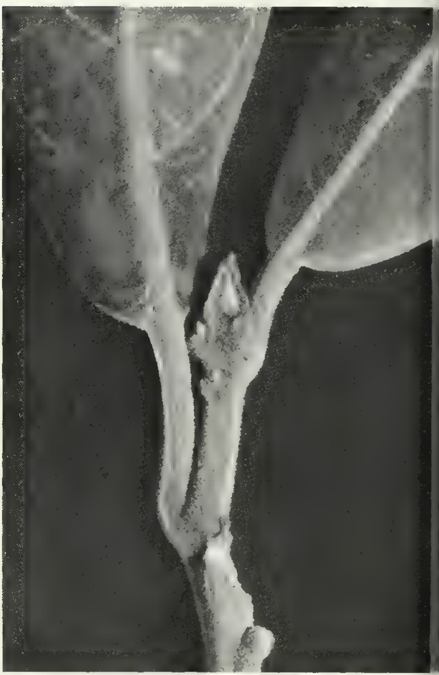
Redbay is browsed heaviest in fall and winter and withstands grazing well. In Mississippi, 40 percent of the annual growth was removed for 2 or 3 years without causing death. On heavily stocked ranges, plants whose foliage is entirely accessible to deer may be killed.

Fire stimulates seed germination and induces the growth of vigorous, palatable sprouts. Winter burning at 3- or 4-year intervals is probably best for making this species most valuable for deer forage.

The tree is sometimes used as an ornamental because of its fruit and evergreen leaves. The dried leaves are a flavoring for gumbo and meat dishes. The red-colored wood is used for furniture, boatbuilding, interior finish, and cabinets.

Other common names: sweetbay, redbay persea, swampbay, swampbay persea.





Redbay

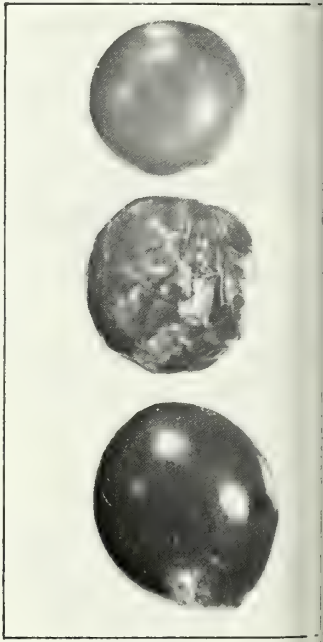
An evergreen tree up to 70 feet tall and trunk diameter of 1 to 3 feet.

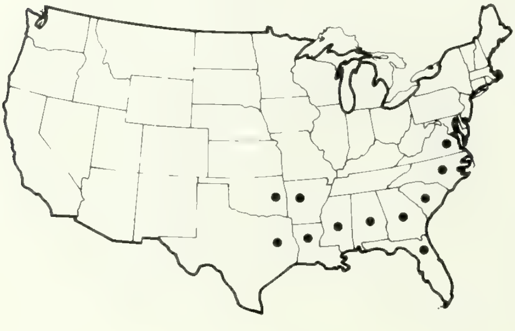
Leaves aromatic, simple, alternate, persistent, bright green lustrous above, glaucous beneath, 3 to 4 inches long, 1 to 1.50 inches thick.

Twigs slender, buds small, generally globose with two outer scales woolly, leaf scars circular, bundle scar solitary, pith near 0.50 twig diameter, angular in cross section.

Flowers small, pale, yellow, borne in axillary panicles. May to July.

Fruit an egg-shaped drupe, dark blue or deep purple, about 0.50 inch long, lustrous; seed solitary, flesh thin and dry. Autumn.





Wild Cherries and Plums/*Prunus* spp.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Wild cherries furnish food for many kinds of birds and mammals. Game birds and songbirds eat the fruits when they ripen in the summer and fall, and sometimes eat them before they are ripe. Songbirds will often gorge themselves with berries and then fly to nearby perches and regurgitate the pits. The fruits are an important staple food for wild turkeys, and are eaten by squirrels, raccoons, pheasants, ducks, grouse, and quail. Fur and game mammals often feed on cherries that have fallen to the ground after birds have taken their harvest on the trees. These mammals also eat the bark of the tree. In spring, buds are eaten by game birds such as ruffed grouse. Deer eat the fruit and, along with rabbits, feed extensively on the twigs and foliage.

The fruits of plums are also eaten by birds and mammals but to a lesser extent than cherries.

The leaves of Prunus are alternate and simple, deciduous or persistent, and mostly serrate. The flowers are bisexual, and have five rounded white or pink petals and many stamens borne on a cuplike base. They are sometimes solitary but mostly in umbel-like clusters or racemes. They often precede the foliage in appearance. The fruit is a drupe, often with thick, edible flesh and usually with a single-seeded stone.

Most members of this genus are sensitive to fire. Plums often occur in thickets and when protected from fire make ideal winter cover for quail and other small wildlife species.

Mexican plum (*P. mexicana* S. Wats.) is a shrub or small tree that grows along river bottoms, lake shores, and hardwood slopes.

Pin cherry (*P. pensylvanica* L.f.) grows on many kinds of soils. In the northern part of its range it is found on nearly all forest types, usually in clearings, where it often forms thickets. In the southern part of its range it grows at elevations of about 2,500 to 4,500 feet. It is intolerant of shade, aggressively invades cleared areas, and grows fast, particularly when young. It seldom lives over 30 years.

Pin cherry can be seeded either in fall or spring. If seeded in fall, the seeds should be cleaned of pulp, soaked in water, and planted one

Mexican Plum

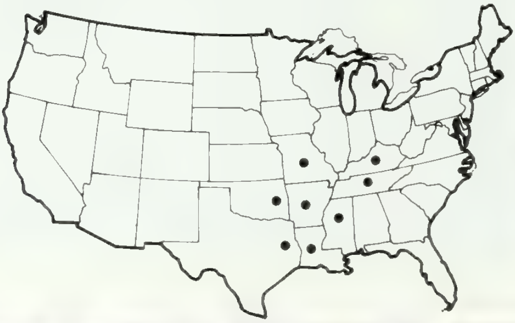
A shrub or small tree up to 25 feet high, with irregular open crown.

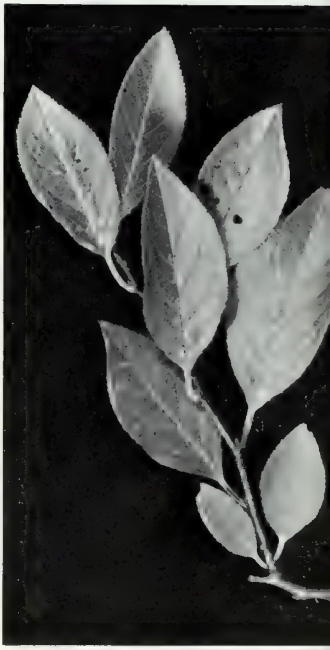
Leaves 1.75 to 3.50 inches long, 1 to 2 inches wide, singly or doubly serrate, upper surface yellowish green, glabrous, shiny, hairy below.

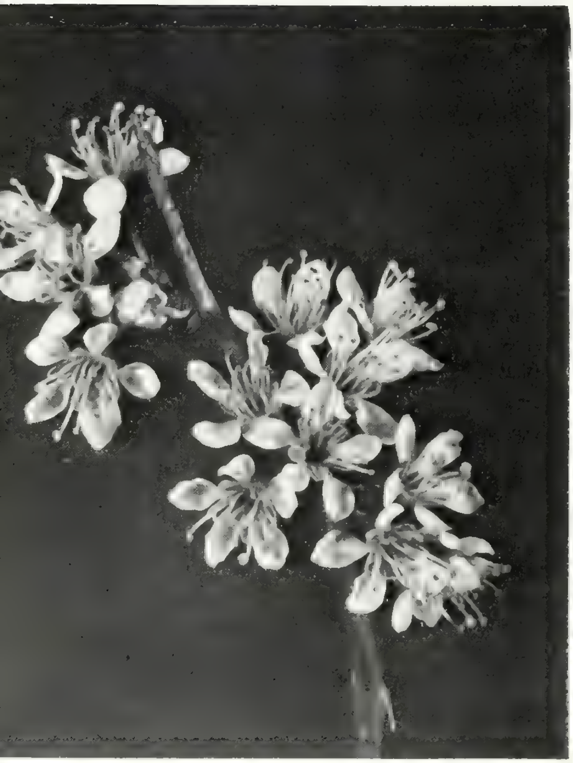
Twigs slender, stiff, glabrous, pubescent early, shiny grayish brown.

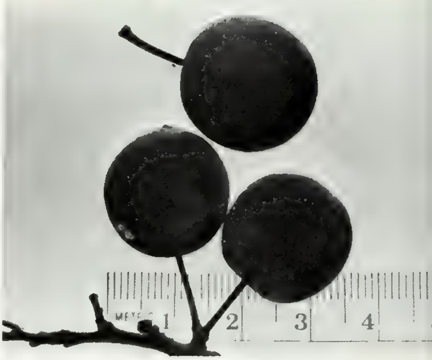
Flowers white, 0.75 to 1 inch diameter. April to July.

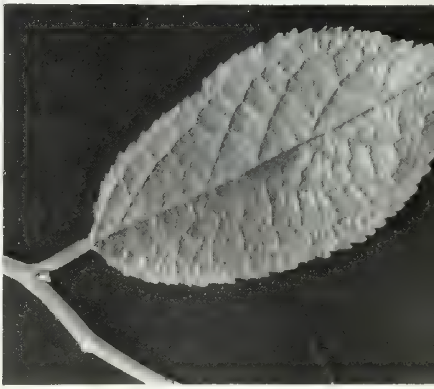
Fruit dark purplish, 0.25 to 1.33 inches in diameter, flesh juicy; stone oval, smooth. July to September.











Pin Cherry

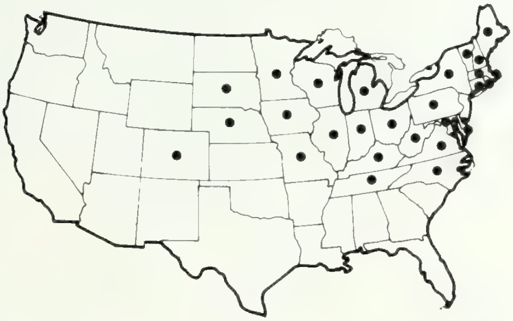
A small tree 30 to 40 feet high, 18 to 20 inches in diameter at breast height.

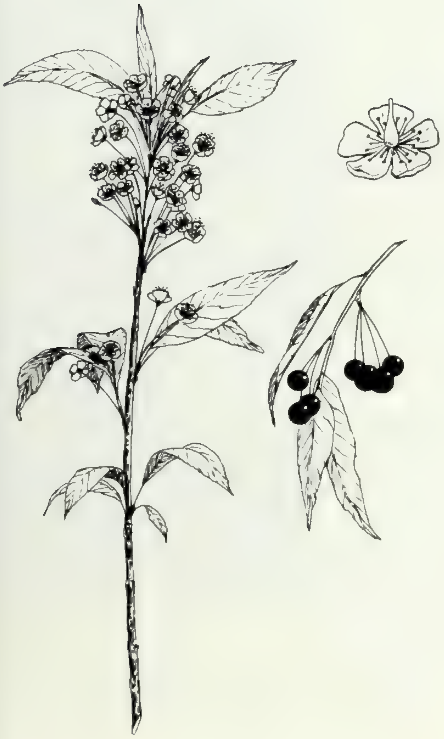
Leaves oblong, finely and sharply serrate, lustrous above, green and glabrous beneath, 3 to 4 inches long, 0.75 to 1.25 inches wide.

Twigs light red, glabrous, lustrous, covered with pale lenticels, short, thick spur-like branchlets, winter buds ovoid, 0.50 inch long, bright red-brown scales.

Flowers 0.50 inch in diameter, white. May.

Fruit, 0.25 inch in diameter, thick light-red skin, thin flesh, stone oblong, 0.20 inch long. July to September, may persist into fall.





inch deep in mulched beds. If held over winter seeds should be stratif in moist sand for 60 days at 68° to 86°F, and then for 90 days at 41°

Pin cherry is occasionally planted as an ornamental. Once established it maintains itself until overtopped by competing trees. It is, however, susceptible to several diseases and insects and has a shal root system. The fruits are eaten by humans.

Other common names are bird cherry, fire cherry, northern pin cherry, pigeon cherry, wild red cherry.

Black cherry (*P. serotina* Ehrh.) grows on all except very swampy or dry sites within its range and in association with a great many othe hardwoods. Growth is best in the southern portion of the northern hardwood type. The species is intolerant of shade, and tends to dominate secondary succession initiated by fire, windthrow, or loggin especially after clearcutting mature northern hardwoods.

Individual trees produce some fruit nearly every year and tend to be consistent in fruit production. In a fully stocked 40-year-old northern hardwood stand in Pennsylvania, fruit yields of black cherry were as high as 120 pounds per acre. Fruit fall begins at ripening. Before germination will take place, the seed requires a period of afte ripening that usually occurs during winter on the forest floor. For artificial planting, seed should be stratified in moist sand or peat for 90 to 120 days at 41°F, or soaked 30 minutes in H_2SO_4, or a combination of the treatments.

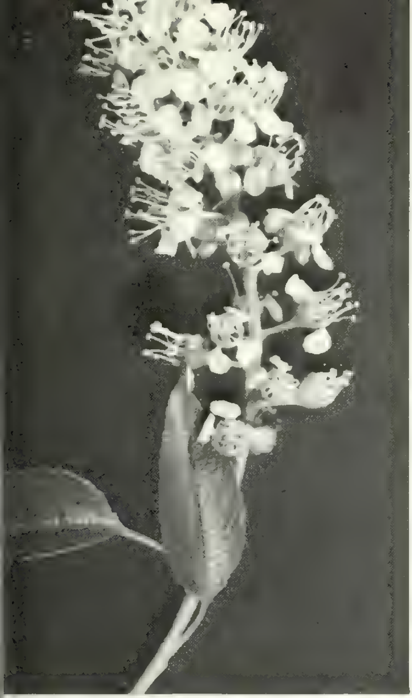
Fruit contains moderate amounts of crude protein, phosphorus, and calcium, but is high in crude fiber.

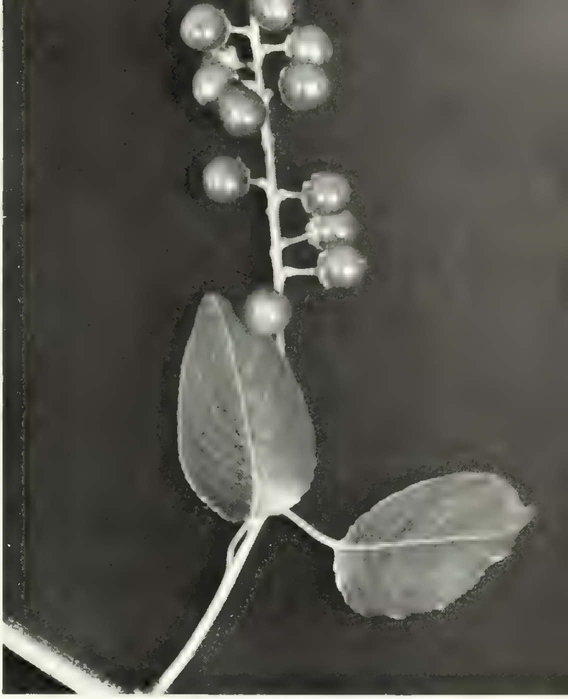
In even-aged stands the growth of black cherry is rapid for the fi 45 to 50 years. The trees require a free or dominant position to thriv If dominant or co-dominant in pine stands, the black cherries make good growth, but those in the understory decline in growth or die ou Black cherry responds little to thinning. Practically all black cherry seedlings may be destroyed by rabbits or deer unless protected in so way.

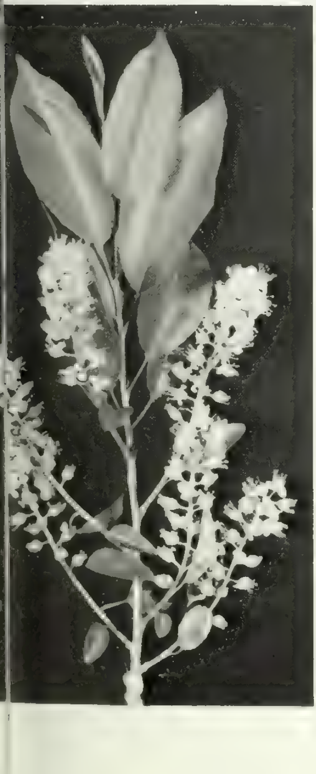
Black cherry is highly susceptible to fire; however, after very hot fires, most top-killed trees resprout from the base.

The fruits of black cherry are used for making jelly and wine and sometimes for flavoring rum and brandy. The bark is used medicinall as a cough remedy. The leaves and twigs contain cyanic acid, and wil foliage is poisonous to livestock. Apparently, deer can eat unwilted foliage without harm.

The wood is used for veneer, furniture, interior finishings, and several woods products.







Black Cherry

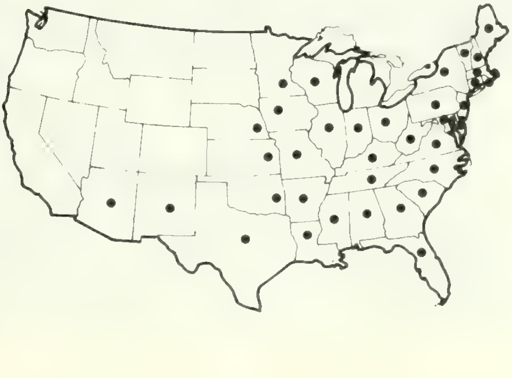
A medium-sized tree, 50 to 60 feet tall and 2 to 3 feet in diameter, with long, straight, clean cylindrical bole.

Leaves 2 to 6 inches long, 1.50 inches wide, margin finely serrate, dark green and very lustrous above, paler below, simple, alternate.

Twigs with bitter almond taste, slender, reddish brown; terminal buds 0.20 inch long, ovate, chestnut brown; lateral buds smaller; leaf scars small, half round.

Flowers white, in drooping panicles, 0.25 inch diameter. March to June.

Fruit a drupe, 0.33 to 0.50 inch diameter, black when ripe, flesh dark purple, stone oblong, 0.33 inch long. June to October.



Flatwoods Plum

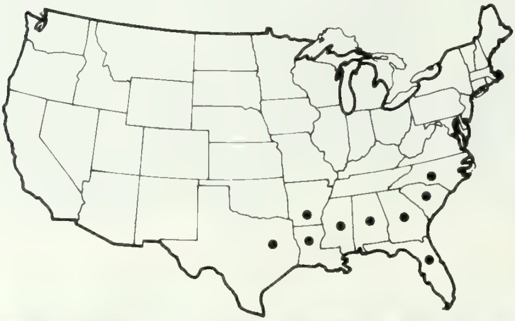
A shrub or small tree 15 to 20 feet high with short, crooked trunk occasionally forms thickets.

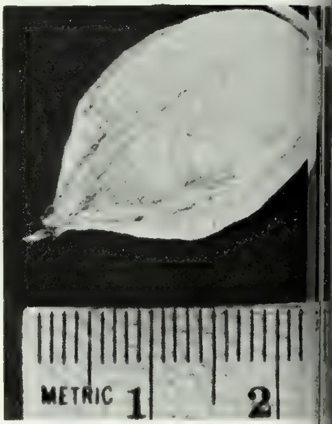
Leaves 2.50 inches long, glabrous above, pubescent beneath.

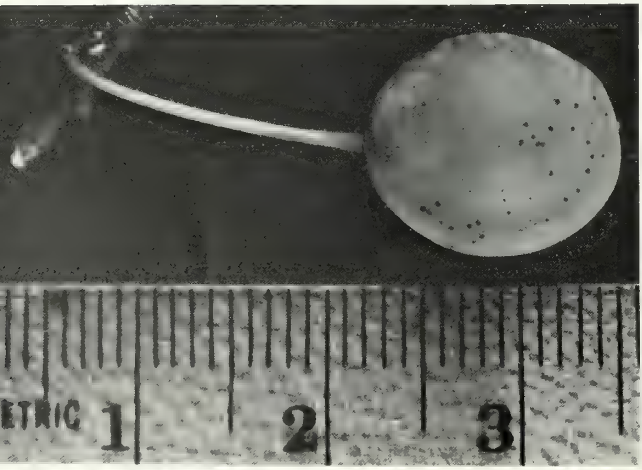
Twigs slender, spurlike, reddish brown, lustrous, glabrous, winter buds 0.06 inch long, chestnut brown scales.

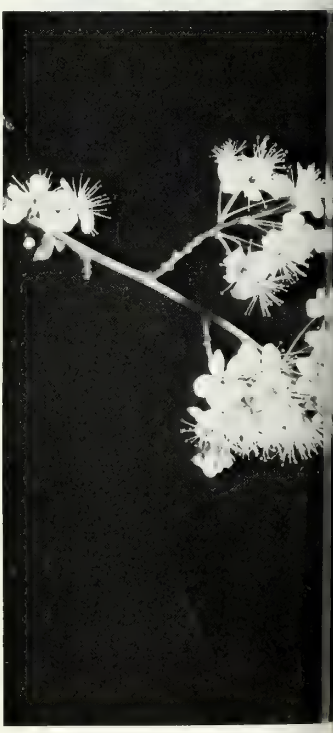
Flowers white, 0.50 to 0.75 inch broad. March to April.

Fruit dark purple, sometimes red or yellow, bitter-sour and astringent to taste, stone oval, 0.50 inch long, rough. Late summer.









Other common names are mountain black cherry and rum cherry.

Flatwoods plum (*P. umbellata* Ell.), grows on sandy soils in open pine and hardwood forests of coastal areas. The fruit is low in crude protein, moderate in phosphorous and calcium, and high in nitrogen-free extract. Deer eat both the fruit and leaves. Seed germination is hastened by stratification for 90 days at 41°F in moist sand or peat. The fruit is used for jellies and preserves.

Other common names: Hog plum, sloe, black sloe.

Shining Sumac/*Rhus copallina* L. var. *copallina*

Malcolm Edwards
Forest Service, USDA
Atlanta, Georgia

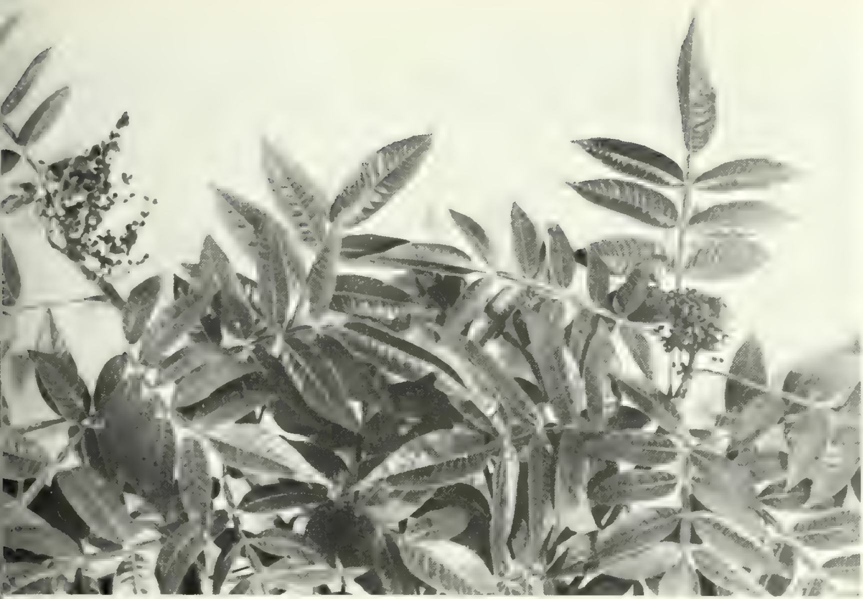
This species grows in dense thickets in old fields, along roadsides, and near powerlines. It is usually associated with broomsedge and blackber The plants grow well on dry acid soil and persist in the understory unti canopy closure.

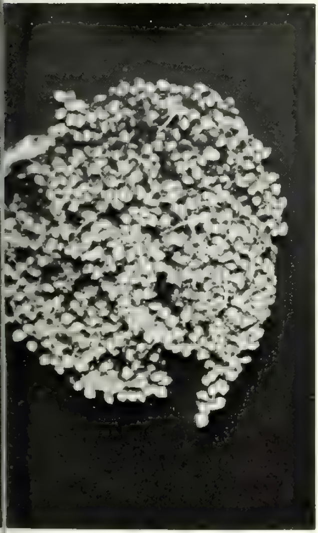
Fruits are eaten by many species of game birds, particularly ruffec grouse, and by songbirds. Entire fruiting heads are eaten by deer. The bright-red fruit cluster remains on the plant into the winter and is availal when more desirable foods are scarce. Fruits often serve as emergenc food for turkey. There are approximately 1,500 to 2,500 seeds per he Rabbits feed on the bark, twigs, and fruit. The plant is occasionally browsed by deer. It will tolerate about 20 percent browsing without damage; however, plants were reduced 30 percent by deer browsing outside an enclosure on the Pisgah National Forest in North Carolina.

The fruit is high in crude fat and phosphorus and low in protein.

Shining Sumac is often planted as an ornamental because of its brilliant red leaves and maroon colored fruit. The fresh berries taste like lemon. The bark and leaves are used for tanning.

Other common names: flameleaf sumac, dwarf sumac, winged sumac, and sumac.





Shining Sumac

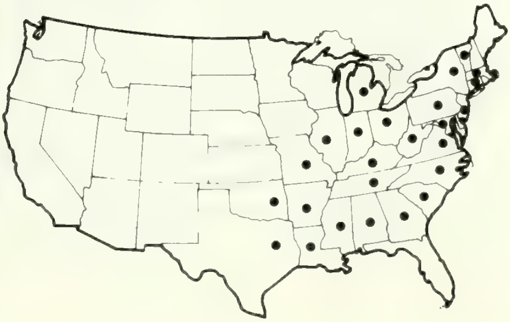
A slender-branched shrub or small tree up to 25 feet tall.

Leaves alternate, pinnately compound, 5 to 12 inches long; rachis pubescent, broadly winged; leaflets 7 to 11, 1 to 3.50 inches long, 0.50 to 1.25 inch broad, lustrous, glabrous to pubescent above, hairy and glandular below.

Twigs green to reddish-brown, velvety pubescence; buds silvery tan, pubescent and without scales, terminal bud absent; leaf scars horseshoe-shaped encircling buds half way. Bundle scars many, pith dark tan, 0.50 stem diameter, sap milky and sticky, lenticels dark rusty-brown and numerous.

Flowers borne in a densely pubescent, terminal compact panicle, petals greenish-white. July to September.

Fruit a red, glandular, hairy drupe, 0.12 to 0.16 inch diameter, compact panicles erect or drooping, seeds solitary, smooth. Ripens in fall, persists through winter.



Smooth Sumac/*Rhus glabra* L.

Malcolm Edwards
Forest Service, USDA
Atlanta, Georgia

Smooth sumac is usually found in old fields with broomsedge and blackberries. It appears shortly after clearing and responds well to disturbances such as fire and timber cutting.

The fruit is eaten by many kinds of game and songbirds. Bobwhit quail eat it year around, and the seeds have reportedly comprised 50 percent of crop contents. Birds cannot sustain weight on a heavy diet of sumac, and it is normally eaten with other foods. It is sometimes regarded as a "stuffing" or an emergency food; however, at times it is eagerly eaten by cottontails, white-tailed deer, ruffed grouse and wild turkey. Browse is eaten by deer and the bark by squirrels and rabbits during the winter.

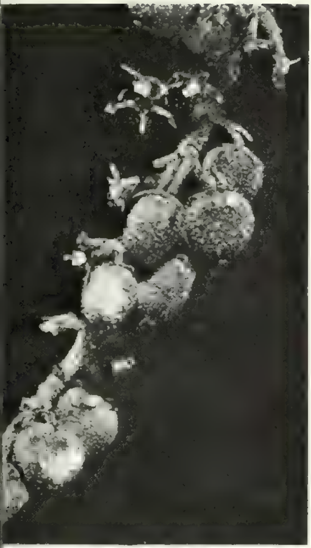
The fruits are low in crude protein, but high in crude fat, and moderate in phosphorus.

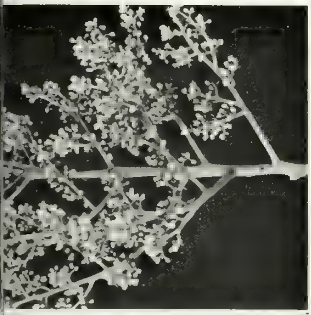
Fruit production is consistent. There are approximately 2,000 seed per head.

Invasion of new areas is by seed, but established sumac reproduc primarily by rootstocks.

Smooth sumac is widely planted as an ornamental because of its brilliant colors in fall. Also, it is occasionally used for erosion control and shelterbelt plantings. Various parts of the plant have been used fo medicinal purposes and for staining and dyeing.

Other common names: white flameleaf sumac, dwarf sumac, southern sumac, and scarlet sumac.





Smooth Sumac

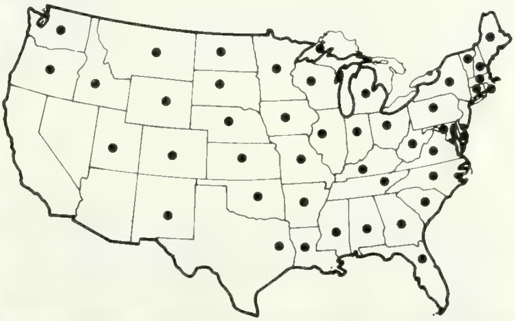
A thicket-forming shrub or small tree attaining a height of 20 feet.

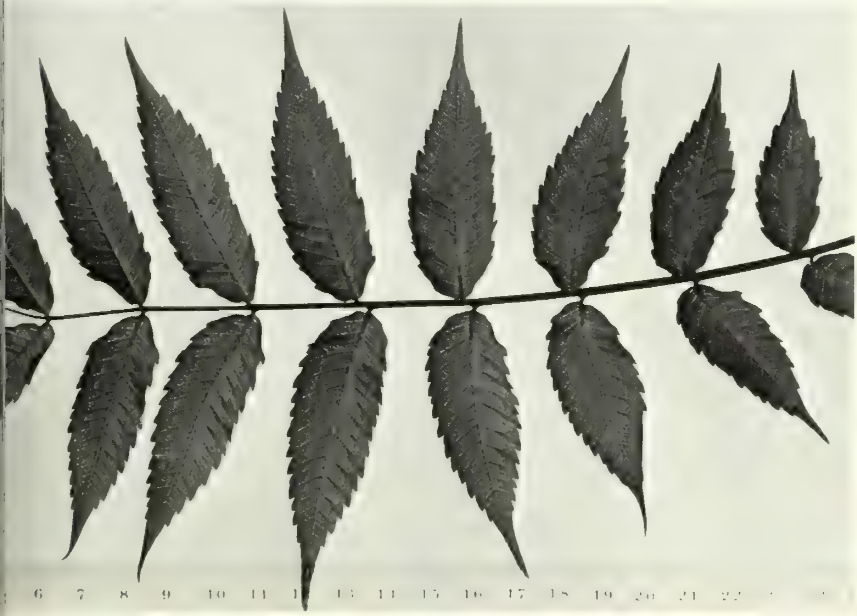
Leaves alternate, pinnately compound, 11 to 31 leaflets, sharply serrate, dark green above, lighter to white below, leaflets 2.50 to 4.75 inches long, 0.50 to 1.25 inches broad.

Twigs glabrous, tan to blotchy gray, buds with tan to silvery dense pubescent, true terminal buds absent, leaf scars encircling buds, bundle scars many, pith orange, half diameter of twig, sap milky and sticky, lenticels light brown and scattered.

Flowers in terminal compact panicles, petals white. June to August.

Fruit a drupe 0.16 inch long, covered with short, red velvety hairs, one seeded, stone smooth. September to October.





Common Poison Ivy/*Rhus radicans* L.

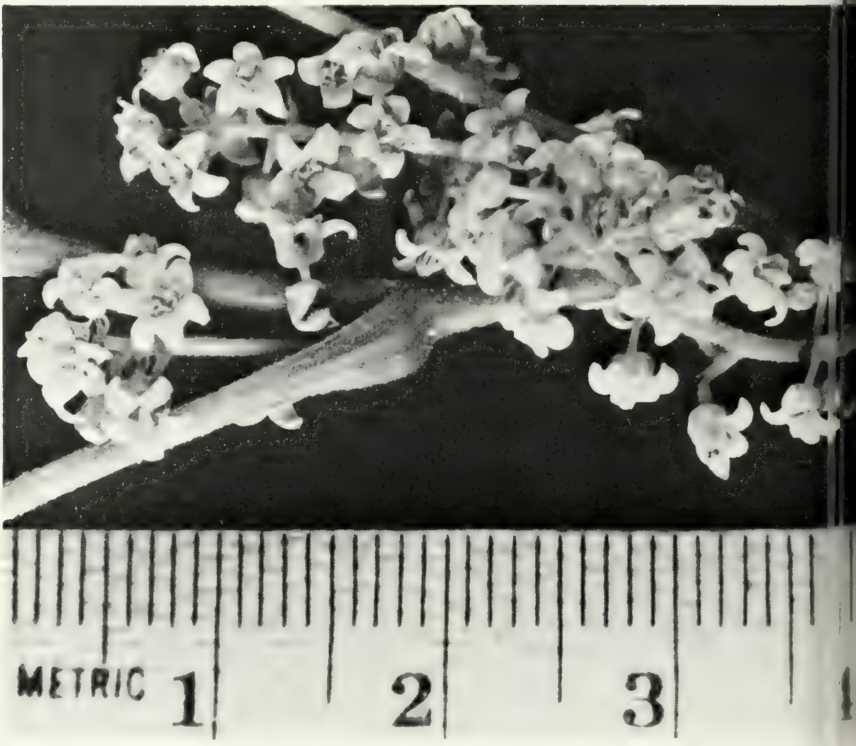
Malcolm Edwards
Forest Service, USDA
Atlanta, Georgia

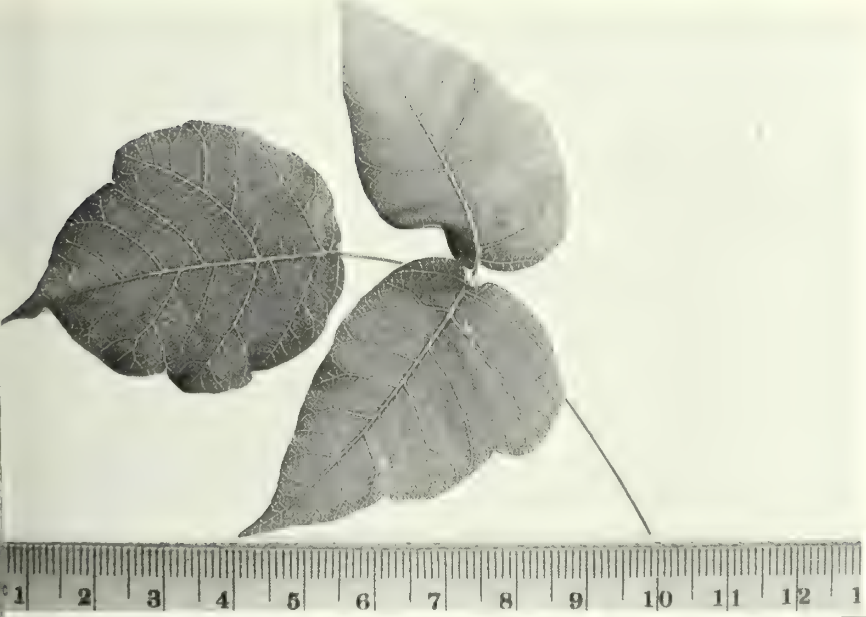
This shade-tolerant species is common from the first stages of plant succession to a climax forest under a wide range of soil conditions, and from moist shaded sites to dry exposed ones.

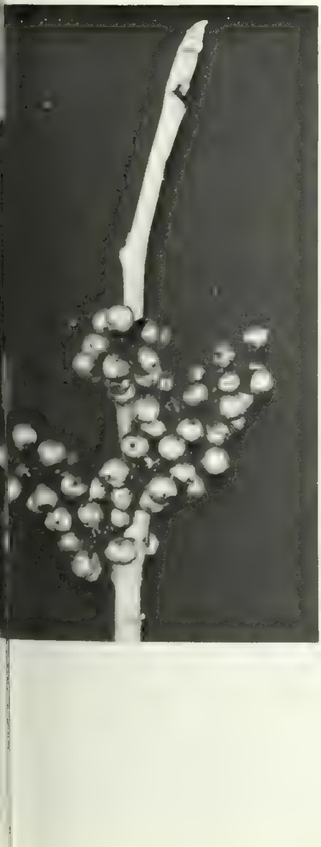
The fruit is eaten by many kinds of birds, including quail, pheas wood ducks, ruffed grouse, and wild turkey. It comprises a significan portion of squirrel diet in bottomland hardwoods in years when othe mast is sparse. Deer eat the fruit and lightly browse the leaves and tw

Upon contact with the skin this plant produces blisters and erup accompanied by intense itching and burning. It is also reported to ha some medicinal uses, and the sap is sometimes used for making var

Other common names: three-leaf ivy, climbing ivy, poison-oak, mercury, black mercury vine, and cow-itch.







Common Poison Ivy

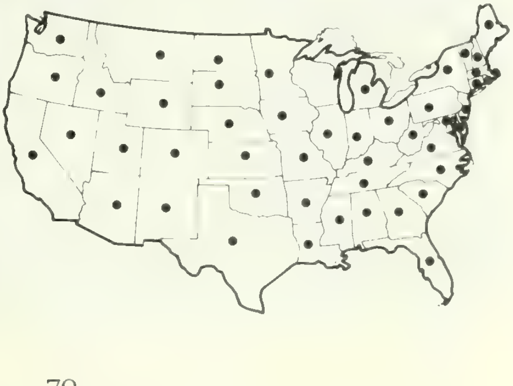
A poisonous suberect shrub or woody-stemmed vine.

Leaves deciduous, trifoliate, variable in shape and size, dull green and glabrous above, paler and pubescent below, 1.50 to 6.75 inches long, 0.50 to 4 inches wide.

Twigs climb by aerial rootlets with disk-like suckers which adhere to support; stem woody, suberect where by itself, dark reddish-brown to grayish-tan or brown, leaf scars large, V-shaped, five bundle scars, buds naked.

Flowers borne in axillary panicles 1 to 4 inches long, small greenish-white, fragrant. May to July.

Fruit a persistent drupe, clustered, 0.12 to 0.25 inch in diameter, dull white, waxy, glabrous or sparsely pubescent. August to November.



***Staghorn Sumac*/*Rhus typhina* L.**

Malcolm Edwards
Forest Service, USDA
Atlanta, Georgia

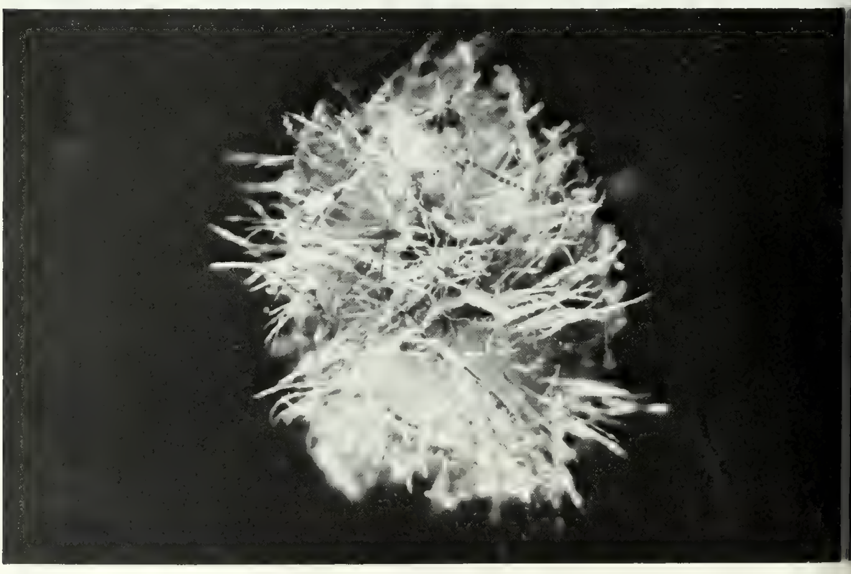
This open-growing species is found in dry, gravelly or rocky soil along forest edges and occasionally in fairly dense woods. Typical growing sites include abandoned fields, roadsides, right-of-ways, fence rows, and young plantations. Plants spread by roots and are generally in clusters. Although growth is rapid plants are short-lived.

The fruits are eaten by many kinds of birds including mourning dove, bobwhite quail, and ruffed grouse, and by mammals such as skunk, white-tailed deer, cottontail, and opossum.

Field plantings may be established from seed either in fall or spring. To insure adequate germination, seeds should be scarified in concentrated sulphuric acid for 1 to 4 hours.

The wood is occasionally used for cabinets or small articles of furniture. The root, bark, and leaves are rich in tannin. The crushed, acid fruits, when steeped in water, make a cooling drink. Plants are sometimes used for erosion control and as ornamentals.

Other common names: velvet sumac, hairy sumac, American sumac, and Virginia sumac.



Staghorn Sumac

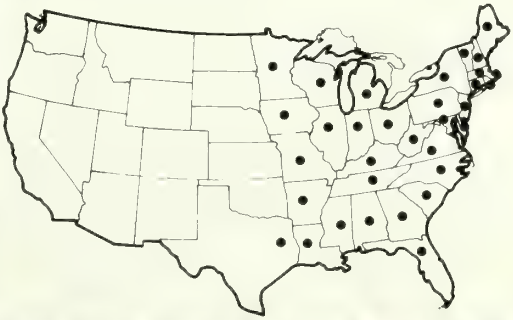
A stout thicket-forming shrub, up to 40 feet tall and 3 to 14 inches in diameter at breast height.

Leaves alternate, deciduous, odd-pinnately compound, 5 to 24 inches long, rachis green to reddish, soft velvety hairs, leaflets 9 to 31, opposite, 1.50 to 6 inches long, 0.33 to 1.75 inches wide, upper surface light to dark green, dull, lower surface whitish and hairy on the veins.

Twigs stout, brittle, brown to orange, branches densely pilose, numerous lenticels, buds tan, conic, brown, hairy, leaf scars horseshoe-shaped, bundle scars in clusters of three, pith round, orange-brown.

Flowers in dense, terminal greenish-yellow panicles, staminate, 7 to 12 inches long, 4 to 6 inches wide; pistillate smaller, erect. June to July.

Fruit dense, terminal conical panicles, 6 to 8 inches long, 2 to 4 inches wide, drupes 0.12 to 0.16 inch long, with long velvety hairs, flesh thin and dry, seed pale green to brown. June to September but persistent through winter.



Dewberries, Blackberries, and Raspberries/Rubus **spp.**

Daniel W. Lay
Texas Parks and Wildlife Department
Nacogdoches, Texas

The many species, hybrids, and varieties of *Rubus* constitute one of the most important sources of fruit for wildlife in the South. Common names applied to three groupings are dewberry, blackberry, and raspberry.

Technically, these species are a part of the rose family, having regular flowers, with five sepals and petals, and alternate leaves. The plants have thorny, semi-woody stems and fleshy fruit with seeds on the surface. Flowers are white with touches of pink.

The three subdivisions can be distinguished by growth habits. Dewberries are prostrate vines with fine spines and glandular hairs. Blackberries are more upright, some to 15 feet, have fluted or ridged green canes, larger spines, and no hairs. Tips of canes may take root when they touch the ground. Leaves of raspberries have white or light-colored undersides and the stems are usually white-powdered.

Dewberry fruiting starts in early spring and continues through mid-summer. The second-year canes have leaves with five leaflets. The blackberry begins fruiting in late May and is the most widespread and significant of the groups. Raspberry fruits mature from June to October.

The green fruits of all three groups turn red before they ripen to a shiny, jet black. The fruits are sought by deer, turkey, quail, raccoons, chipmunks, ruffed grouse, squirrels, and many brids, including woodcock. The fruits are eaten mainly when fleshy, but even the dried persisting berries are eaten to some extent in fall and winter.

One study of fruit used by deer in eastern Texas revealed blackberry seeds in deer droppings 23 times in 30 samples collected during June. The period of use was May to September, which is the approximate period of availability. The leaves of blackberry are among the first to appear in late winter. At this time they are highly palatable and on many ranges are a significant part of the browse consumed by deer. Fruits are high in nitrogen-free extract, low in crude protein, and moderate in phosphorous and calcium.

Blackberry follows herbaceous weeds in invading disturbed sites and is the forerunner of trees and shrubs which shade it out. It is

Dewberry

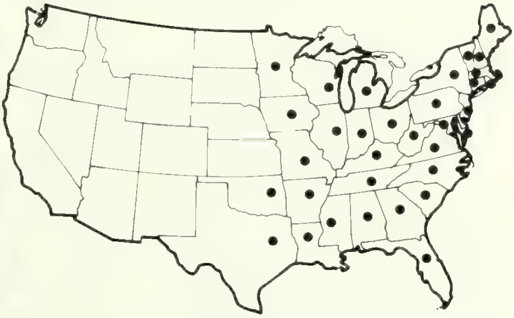
Grows usually low on ground in dry or wet areas.

Leaves green on both sides, three leaflets, compound, serrated.

Twigs erect at first then trailing, sends up floral branches a few inches high which bear flowers and fruit, prickles.

Flowers borne singly on floricane, white. April to June.

Fruit receptacle becomes soft and juicy, comes off the plant with drupelets, black. June to August.



Blackberry

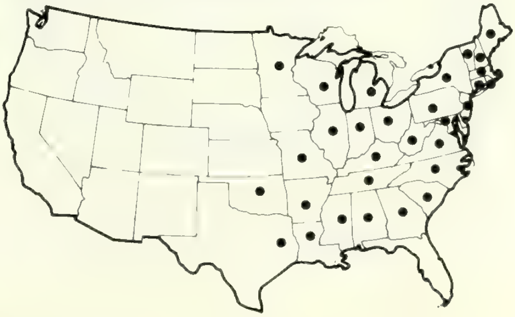
Grows in dense thickets, up to 4 feet tall in dry and wet areas from lowlands to hills.

Leaves quite variable in size and shape, usually green on both sides, compound and simple.

Twigs erect or arched, green or reddish-brown, stems biennial, first year canes vigorous, leaves commonly have five leaflets, second-year canes produce short branches which bear flowers and fruit, tips of canes take root when they touch ground, prickles.

Flowers borne on floricane in clusters, white. May to July.

Fruit receptacle becomes soft and juicy and comes off with drupelet, 0.50 to 1 inch long, deep purple or black. May to July.



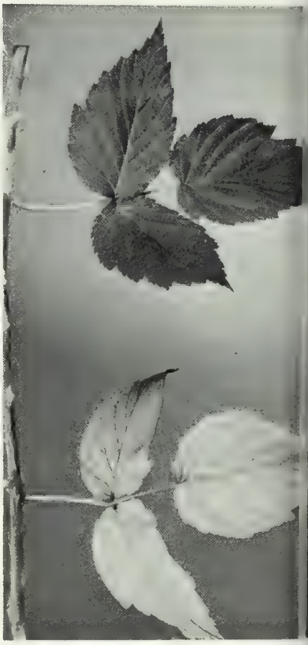
favored by soil disturbance, fire, and overstory removal and grows best in full sunlight. The extensive, nearly impenetrable thickets are especially good cover for birds, rabbits, and other small rodents and are common nesting sites for small birds.

Seeds and rootstocks persist in most soils, ready to grow when conditions are favorable. Establishment should not be difficult where the plants are not present. No seed is available commercially, but one can transplant local rootstocks. Sandy, well drained soils are best, although many river bottoms have heavy growths of blackberry. Blackberries produce prolifically when grown in full sunlight. When grown in shade fruit production is low, but the stems are nearly thornless.

After the second year, canes die and add to the density of the "briar patch." For best vigor, stands should be stimulated with fire or disking when their fruit production declines or when they get too tall and dense for the fruit to be available.

Some quail hunters have had occasion to cuss the thorny rubus species because quail often retreat into their protective cover. But for birds and many other types of wildlife, dewberries, blackberries, and raspberries are important and necessary food plants.

Raspberry



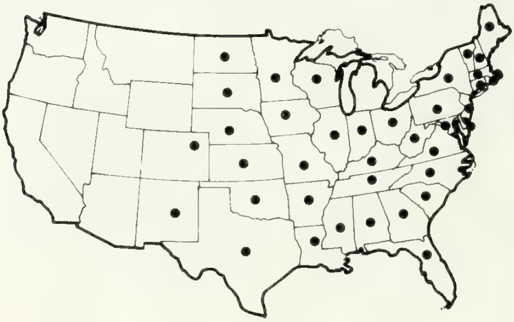
Grows in dense thickets on dry or wet places.

Leaves variable in shape and size, commonly compound, three leaflets, usually white or light-colored on underside.

Twigs erect or arched, root at tip, smooth, cylindrical, usually with whitish bloom that is easily rubbed off, leaving a purplish or light-colored stem, second year canes produce short branches which bear flowers and fruit, prickless. or prickles.

Flowers white, or short spurs. May to July.

Fruit an aggregate of drupes that comes away in a thimble-shaped unit, receptacle remains dry and hard, red or black. June to October.



***Palmetto*/*Sabal* spp.**

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Sabals are members of the palm family and have a berrylike or drupelike fruit.

Scrub palmetto (*S. etonia* Swingle) grows primarily in the sand pine-scrub oak forest type along with dwarf palmetto. White-tailed deer feed heavily on the fruits even when unripened. Over 100 pounds per acre of palmetto fruit may be produced during a good year.

Other common name is corkscrew-palm.

Dwarf palmetto [(*S. minor* (Jacq.) Pers.] grows in dry hills, flatlands, and wet alluvial floodplains.

The fruit is eaten by several kinds of songbirds and by raccoons, squirrels, and white-tailed deer. Fruits are occasionally browsed by cattle. Now and then dwarf palmetto is planted as an ornamental.

Other common name is bush palmetto.

Cabbage palmetto [*S. palmetto* (Walt.) Lodd.] grows in sandy soils along the coastline; in prairies, marshes, pinelands, and hammocks, usually where limestone is near the surface; and throughout the Florida peninsula.

Fruits are eaten by songbirds, bobwhite quail, small mammals, white-tailed deer, and black bear. Fruits are a major winter food of wild turkeys in Florida. The tree may provide the best nesting site available for grey squirrel, and the caracara nearly always nest in it.

The edible bud or "cabbage" is sold precooked in many stores and is also eaten raw as a salad.

Cabbage palmetto is the state tree of Florida and is often used in ornamental plantings. It invades quickly on disturbed soil and is now more abundant than ever.

The young leaf stalk bases are processed commercially for fiber, brushes, and whiskbrooms.

Other common names: Carolina palmetto, common palmetto, palmetto, cabbage-palm.

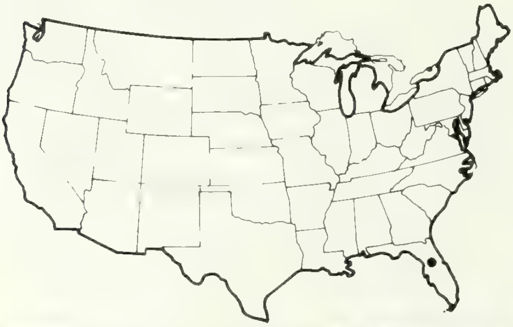
Scrub Palmetto

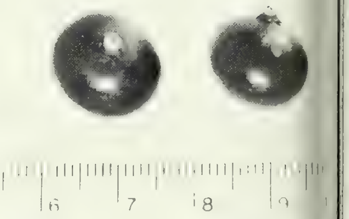
A shrub with a recumbent, twisting stem.

Leaves deeply cleft, fan-shaped, up to 2.50 feet in diameter, with many filaments.

Flower cluster 1.50 to 2.50 feet long, often prostrate at maturity.

Fruit, a black drupe, 0.37 inch or more in diameter.





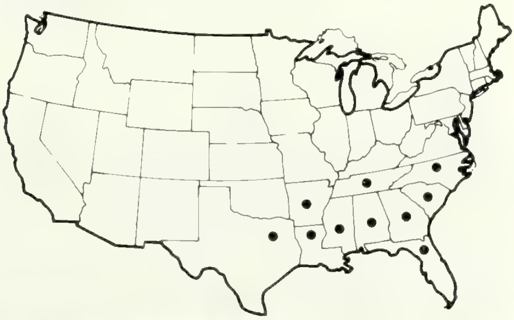
Dwarf Palmetto

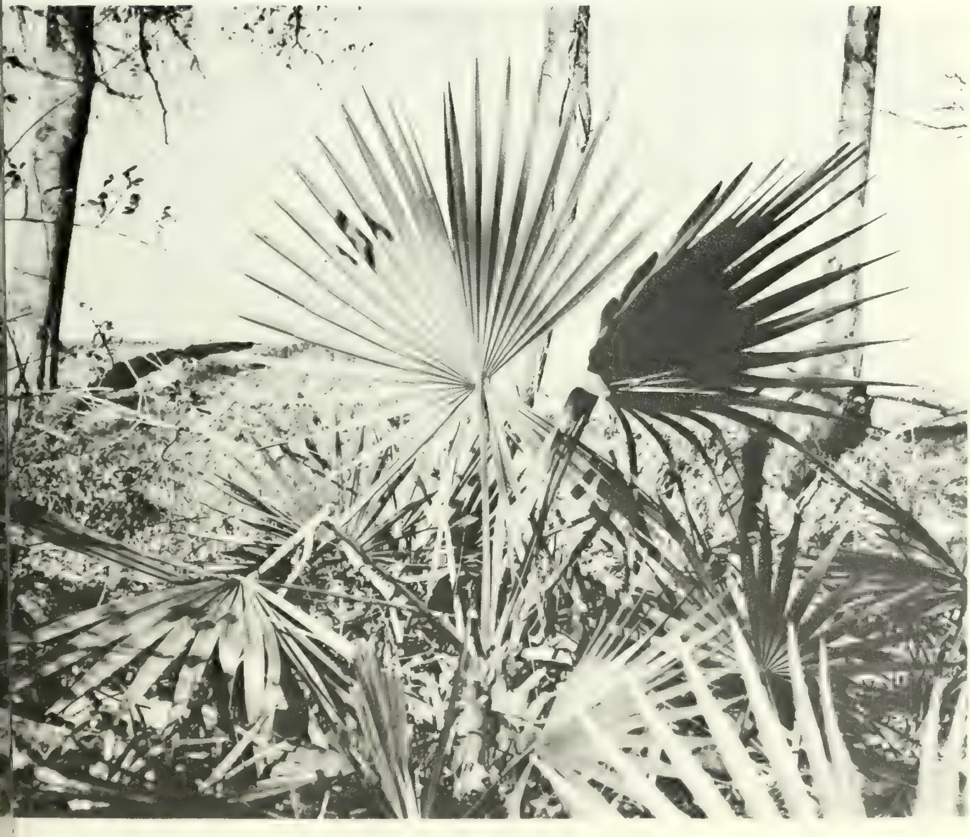
A shrub with two growth phases, stemless in dry hills but with short stems in alluvial floodplains.

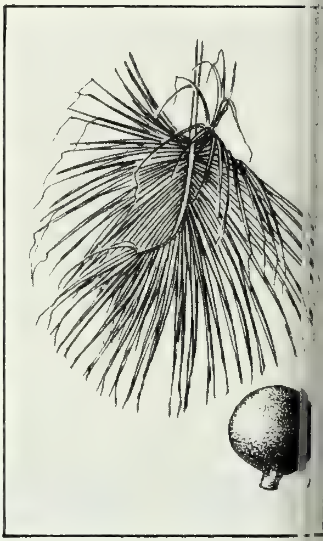
Leaves consist of a stout, usually erect, smooth petiole and a fan-shaped blade 1 to 3 feet in diameter. The leaves have a bluish cast, and are rather stiff without filaments.

Flower cluster elongate 3 to 6 feet long, erect.

Fruit a black, dry, hard drupe 0.25 to 0.33 inch in diameter.







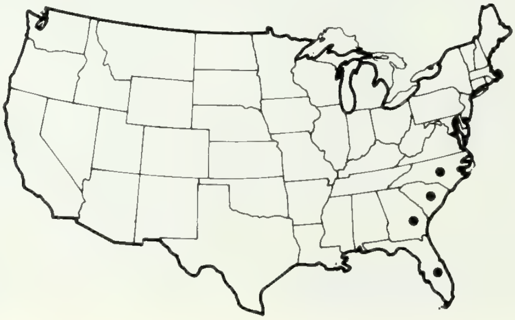
Cabbage Palmetto

A branchless tree up to 80 feet tall and 1 to 2 feet in diameter. The trunk is clothed during early life with decayed leaf stalks (boots) that later fall away and leave a fairly smooth lightly ridged stem.

Leaves persistent, blades fanlike, shiny, and deep green in color, 4 to 7 feet long, segments are free at tips, petioles smooth and as long or longer than blades.

Flowers small, creamy-white, borne in profusion on panicles from leaf axils.

Fruits drupelike, 0.33 inch diameter, seed chestnut-colored and extremely hard, 0.25 inch broad. Large clusters often hang downward.



***American Elder**/Sambucus canadensis* L.

Donald J. Hankla
North Carolina Wildlife Resources Commission
Raleigh, North Carolina

American elder is found on stream banks and in major bottoms and sometimes on moist sites in upland woods. It occurs in full sun but is common in the understory, provided that the canopy allows some direct light to enter.

The fruit is an important source of summer and early fall food for many kinds of songbirds. Robins, mockingbirds, and catbirds eagerly consume the berry-like drupes before they are ripe. Ruffed grouse, quail, wild turkey, and mourning doves eat the fallen fruit. Squirrels, rabbits, raccoons, opossums, chipmunks, and deer feed on the fruit or foliage.

The fruits are moderate in crude protein, and high in crude fat and phosphorus.

Deer preference for foliage varies from low to medium. In the Piedmont and Gulf Coast the rating is generally low, though in Piedmont Georgia it may be used regularly and heavily in September even where honeysuckle and greenbrier are abundant. The foliage is heavily used in Louisiana, but browsing is seldom severe enough to retard normal growth.

American elder is thicket-forming and furnishes excellent nesting cover for small birds. New growth tastes bitter and contains a glucoside that is sometimes fatal to cattle and sheep. The older growth has some forage value.

Before planting, seeds should be scarified with sulfuric acid for 10 to 20 minutes or stratified in moist sand for 60 days at 68° to 86°F alternating daily, then 120 days at 41°F. Untreated seeds sown n the fall ordinarily do not complete germination until the second year.

The fruit is sought for making wines, jellies, and pies. Limited use s made of the plant as an ornamental.

Other common names: elder, sweet elder, common elder, blackberry elder.

American Elder

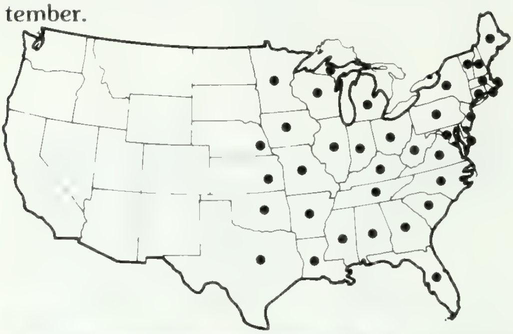
A many-stemmed shrub averaging 7 feet tall.

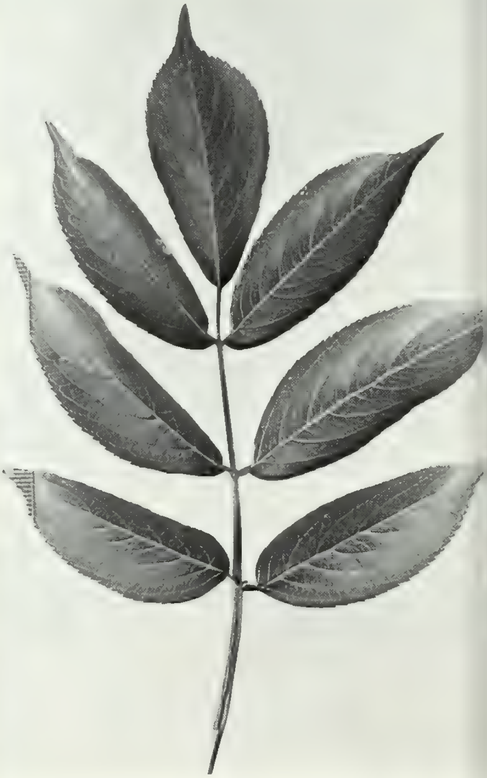
Stems dotted with corklike lenticels, pith white; buds medium-sized, conical, and somewhat depressed.

Flowers white in convex cymes up to 10 inches across. June to July.

Leaves deciduous, upper surface lustrous bright green, lower surface paler, 4 to 12 inches long.

Fruit berry-like in clusters, drupe deep purple, 0.15 to 0.25 inch in diameter. August and September.





Sassafras/*Sassafras albidum* (Nutt.) Nees

Robert G. Leonard
Arkansas Game and Fish Commission
Little Rock, Arkansas

Sassafras grows best in open woods and along fence rows on moist, well-drained sandy loam soils. It is a pioneer species on abandoned fields and on dry ridges and upper slopes, especially after fire. It is highly susceptible to frost and frequently suffers from winter killing in the northern part of the range. On poor sites its growth is short and frequently shrubby.

The fruit is eaten by songbirds, wild turkey, ruffed grouse, bobwhite quail, raccoons, squirrels, black bear, and other mammals. Usually, however, the quantity of fruit is limited. Fruit production is optimum when trees are 25 to 50 years old. Seeds are high in crude protein, moderate in phosphorus, high in crude fat, but low in calcium.

White-tailed deer browse the twigs in winter and the succulent growth in spring and summer. Sprouts are particularly palatable and grazed heavily after a fire or disturbance.

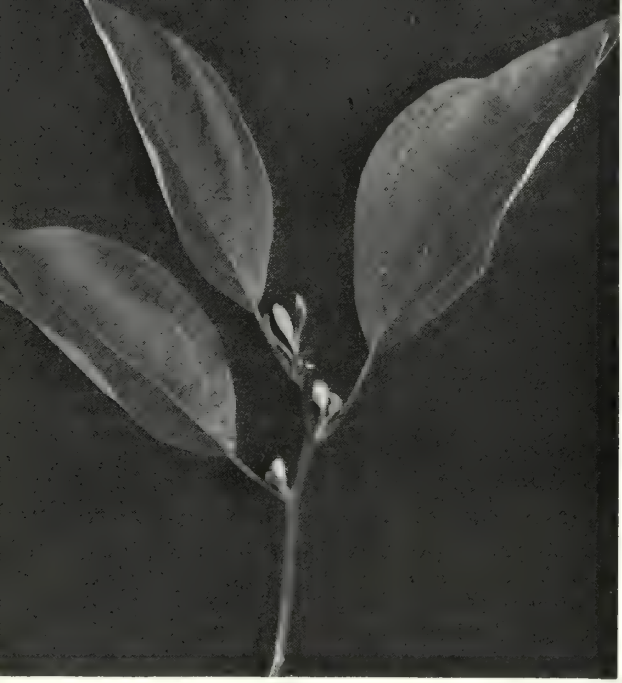
Sassafras seed usually remain dormant until spring although some early maturing seed may germinate in the fall. Stratification for 30 days in moist sand at 41°F breaks natural dormancy.

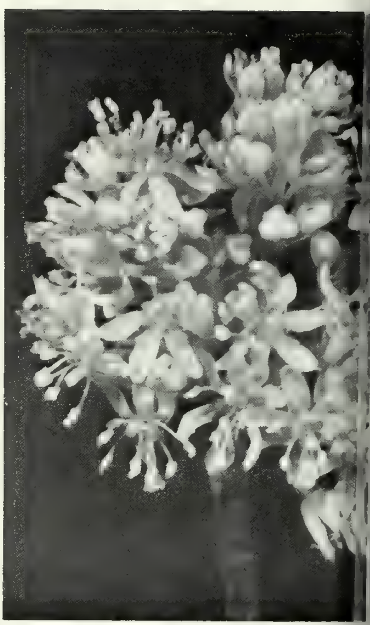
Sassafras is intolerant of shade and reproduction is sparse and erratic except by sprouting. The dense stands often found in woods openings or old fields are from sprouts rather than seed. The species is susceptible to fire damage, but it sprouts readily after a fire.

On good sites where competition is not too severe sassafras grows rapidly; thus the highly palatable sprouts soon grow out of reach for deer unless they are periodically (every 2 to 5 years) killed or cut back by fire or mowing.

The orange wood is durable, coarse-grained and light, but is neither hard nor strong. The wood has been used for cooperage, buckets, boats, posts, and furniture. A tea is made from the outer bark of the roots; an extract of the bark is used as an orange dye for wool. The oil is included in some soaps. When invading pastures and old fields sassafras is considered a weed tree.

Other common name: common sassafras.





Sassafras

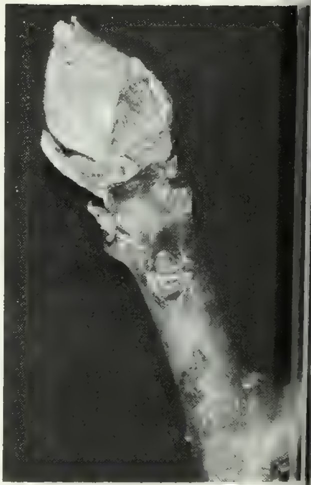
A tree, attaining a height of 90 feet.

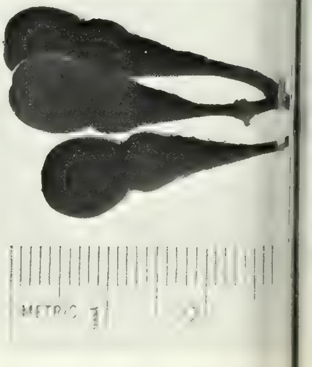
Leaves alternate, simple, deciduous, thin, aromatic, blades 3 to 5 inches long, margin entire or divided into two to three mitten-shaped lobes, bright green above, glabrous beneath, hairy on veins.

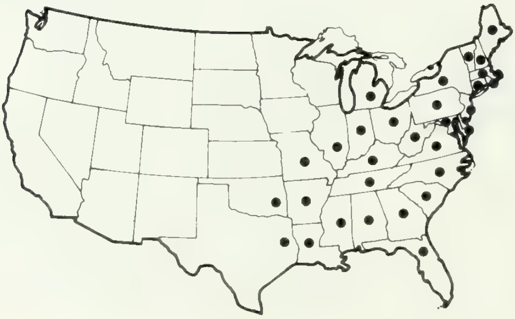
Twigs yellowish-green, pubescent at first, turning glabrous and orange-red later, twig mottled with dark green and grayish brown, pith soft and white, leaf scars half round to crescent shaped, one bundle scar, twigs spicy.

Flowers greenish-yellow, in loose open cluster before leaves unfold, axillary in racemes about 2 inches long. March to April.

Fruit a blue, spicy drupe, lustrous, 0.50 inch long, borne on a thickened, red pedicel, stone solitary, light brown. July to September.







Saw-Palmetto/*Serenoa repens* (Bartr.) Small

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

This species grows on sandy pinelands, prairies, hammocks, or dunes, on acid or alkaline soils. It is frequently the dominant shrub in the fire-dependent flatwoods ecosystem.

Palmetto fruits are heavily utilized by white-tailed deer, black bear, nd feral hogs, and are eaten by wild turkey in winter and spring. Twenty-one pounds of saw-palmetto drupes were taken from the tomach of one bear in Florida.

Saw-palmetto produces vigorous regrowth after burning, but fruiting is reduced. The emerging leaves are grazed by cattle. Mature fronds re occasionally cropped heavily by cattle when on a high protein upplement or when other forage is scarce. For maximum fruit production the plants must be protected from fire.

The leaves are used for Easter decorations, the flowers are a source of honey, and the stems a source of tannic acid extract.

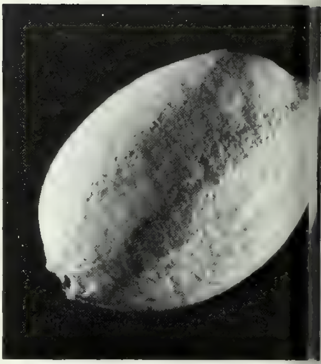
Saw-Palmetto

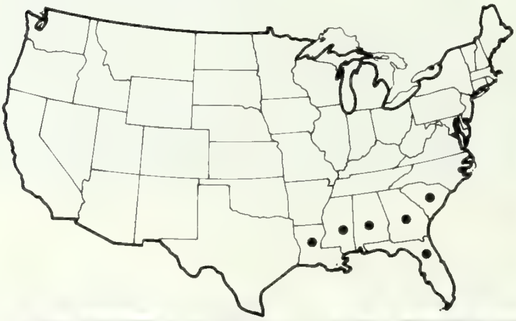
A shrub usually 3 to 7 feet high, with creeping or horizontal stems often rooting beneath, occasionally becoming a small tree in light shade.

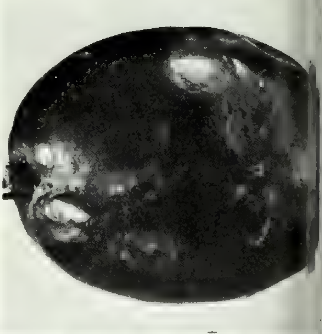
Leaves clustered, erect or ascending, fan-shaped, 1 to 2.50 feet broad, stiff, green or glabrous, petioles longer than blade, armed with sharp, rigid, recurved teeth.

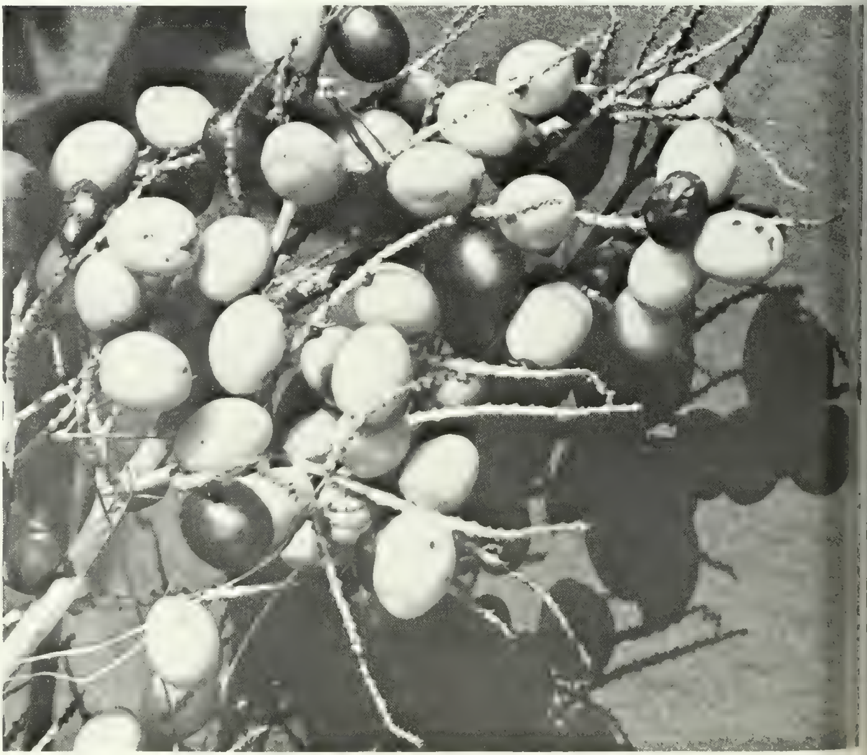
Flowers erect or spreading, elongate, zigzag, usually numerous, white, 0.17 to 0.25 inch long. Spring to early summer.

Fruit an ovoid drupe, black to dark brown, 0.60 to 1 inch long, seeds erect, solitary, panicles weighing up to 9 pounds.









***Viburnum*/*Viburnum* spp.**

Herman L. Holbrook
Forest Service, USDA
Atlanta, Georgia

James C. Lewis
U. S. Fish and Wildlife Service
Stillwater, Oklahoma

Viburnums are typically understory species found on a variety of sites. Rusty blackhaw (*V. rufidulum* Raf.) attains its best growth on moist, rich alluvium but is found on dry sites and at elevations up to 3,500 feet in Virginia and Tennessee. Possumhaw viburnum (*V. nudum* L.) grows in swamps on sandy, acid soils and is often found in pinelands. Arrowwood (*V. dentatum* L.) is most common on sandy soils and moist sites such as wet thickets, swamps, and meadows. It is found on chert soils in Virginia. Mapleleaf arrowwood (*V. acerifolium* L.) is found on dry, sandy or rocky soils, in thickets, on hillsides and on sandstone bluffs. Hobblebush (*V. alnifolium* Marsh.) grows in moist woods and cool ravines. All of the viburnums are fairly shade tolerant and are typically of the mid and late successional stages.

Viburnums have showy, umbrella-shaped clusters of small white or pink flowers that appear in spring or early summer. The simple, deciduous leaves are opposite; the stem at the point of attachment is marked by a characteristic line. Mature fruit is red or blue-black, round or slightly flattened, and about one-quarter inch in diameter. The umbrella-shaped fruit clusters usually contain one to two dozen drupes. Species reproduce vegetatively and by seed. Invasion of new areas is by seed, followed by root suckering or layering of stems. Seed germination is normally delayed until the second spring after ripening.

Viburnums are valuable to wildlife chiefly for their fruit, a one-seeded drupe with a flat stone and thin oily flesh. The fruit is available from late summer through fall and is readily taken by songbirds, ruffed grouse, wild turkey, quail, squirrels, beaver, rabbits, raccoons, chipmunks, and deer. Good seed crops are usually borne every year or two and are heaviest in the open. The twigs, bark and leaves are eaten by deer and beaver. Fruits are low in crude protein and crude fiber and high in nitrogen-free extract and crude fat.

Viburnums are widely used as ornamentals for their showy flowers and their foliage. Many commercial varieties are available on the market.

Mapleleaf Viburnum

A shrub 2 to 6 feet tall, often forming thickets.

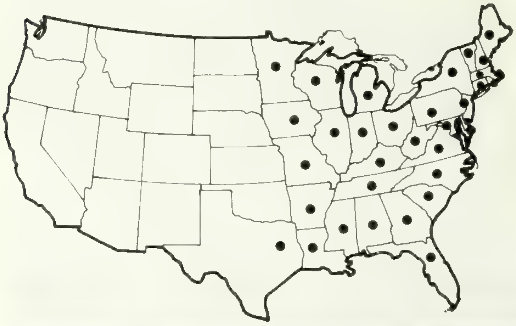
Leaves 1.25 to 5 inches wide or long, lateral veins continuous to margins, lower leaf surface copiously dotted.

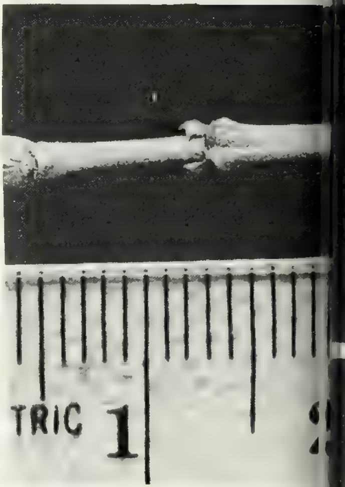
Twigs pubescent, pith narrow, leaf scars narrow, V-shaped to crescent shaped, connecting around twig, three bundle scars, buds yellow to rusty, two or three pairs of visible scales.

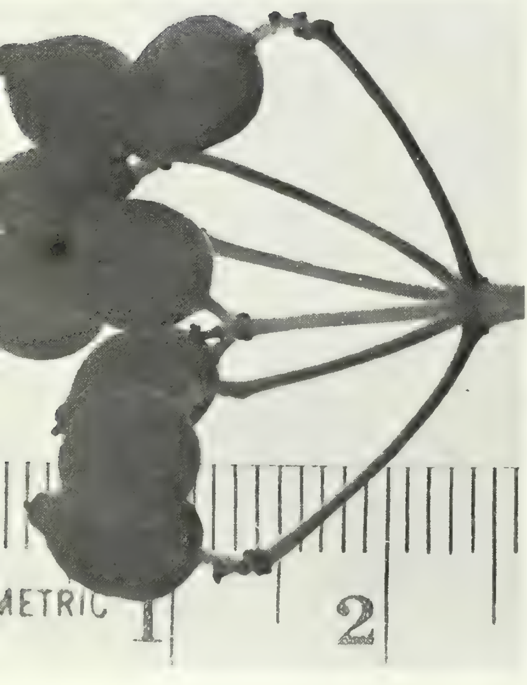
Flowers in cymes 0.75 to 3.50 inches wide. May to August.

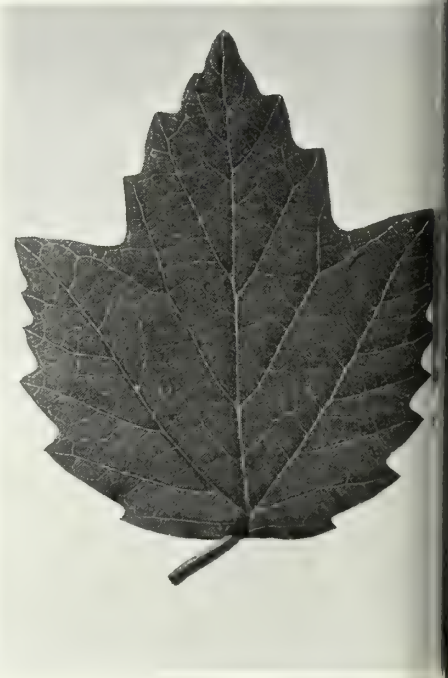
Fruit flattened, with shallow grooves on each side. July to October.

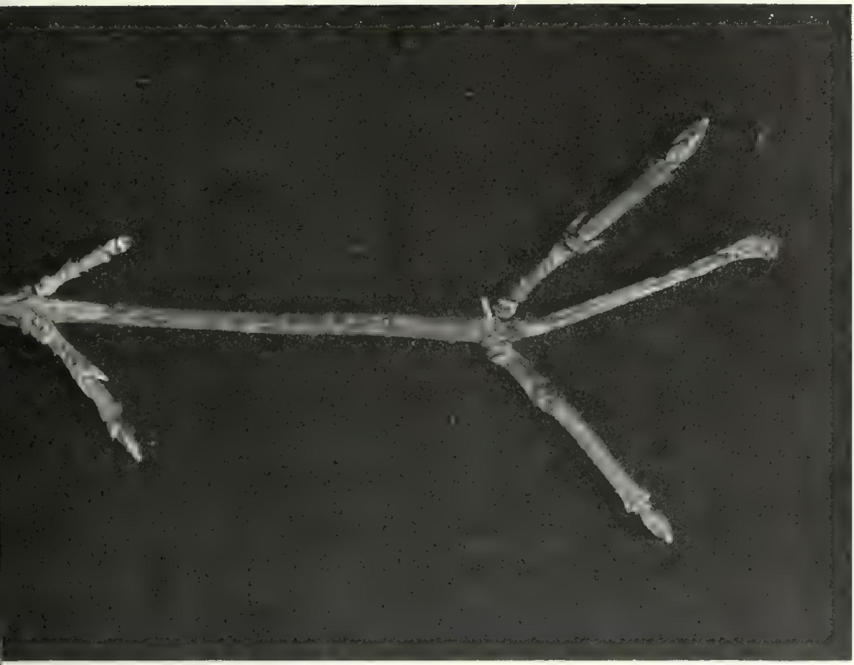
Other common names: ***arrowwood, possumhaw, squashberry, dockmackie.***

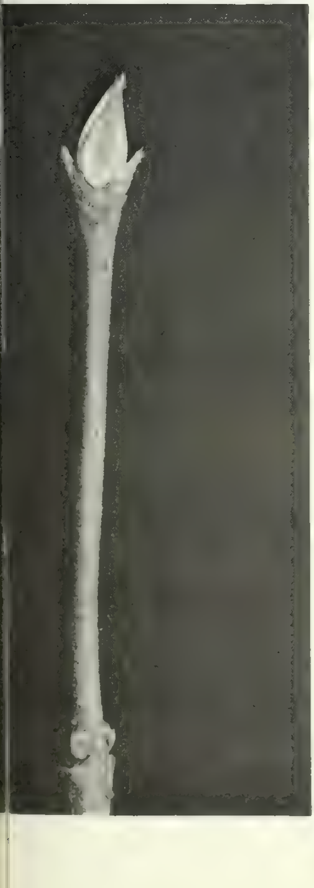












Hobblebush

A straggling shrub 3 to 15 feet tall.

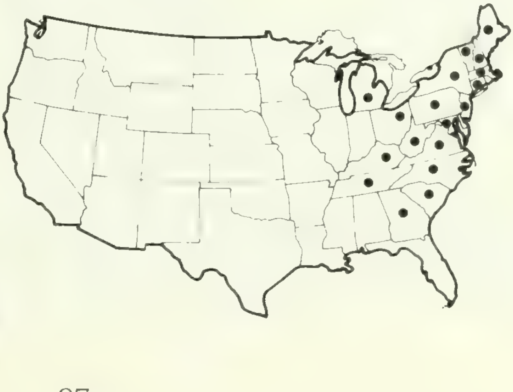
Leaves 3.50 to 8 inches long and nearly as wide, scurfy on underside, lateral venation pinnate, branching several times, ending at serrations of leaf margin.

Twigs scurfy, buds large, naked, scurfy, terminals often exceed 1 inch.

Flower 1 to 2 inches wide, essentially without stalks.

Fruit clusters 1 to 2 inches wide, drupe flattened on one side, grooved on all faces. August to October.

Other common names: ***witch-hobble, tanglelegs, moose-wood.***



Southern Arrowwood

A shrub 3 to 15 feet tall.

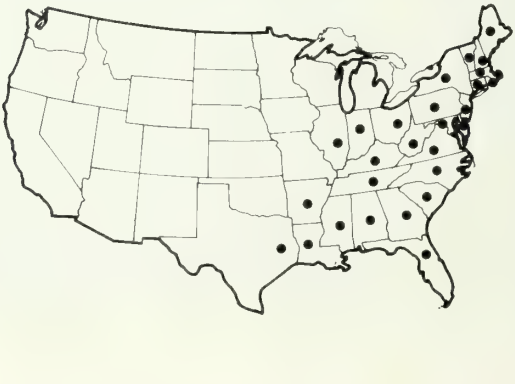
Leaves 1 to 4.50 inches long, veins continuous to margin, many single or tufted hairs at fork of branched veins on the under surface.

Twigs glabrous, pith continuous and white to rusty in color, leaf scars narrow, V-shaped, continuous around twig, three bundle scars, terminal buds acute with two or three pairs.

Flower cymes 1.25 to 4.50 inches wide. June to August.

Fruit with shallow grooves on one side. August to November.

Other common names: ***arrowwood viburnum, mealy-tree, withe wood.***



Possumhaw

An irregularly branched shrub or small tree, rarely over 20 feet.

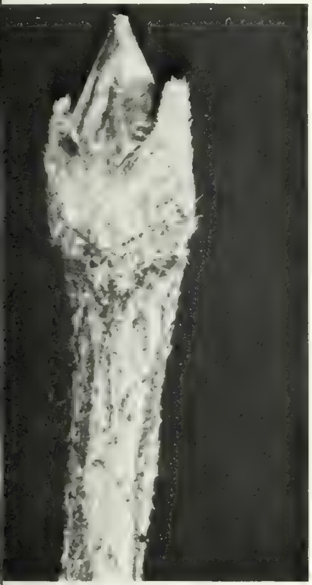
Leaves leathery, shiny, 2 to 5 inches long, 1 to 2 inches wide, olive green to dark green above, lower surface paler and with rusty brown scales.

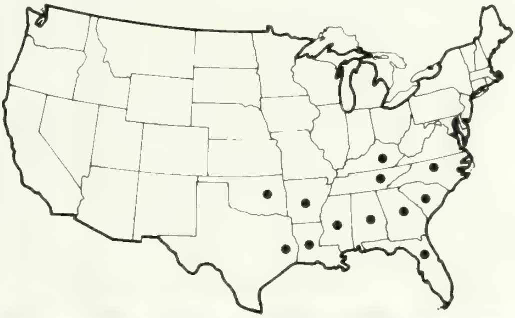
Twigs reddish brown to purple brown, few minute hairs, older twigs gray and glabrous, leaf scars, U- to V-shaped and narrow, encircling young stem but later separated, three bundle scars, buds slender, 0.50 inch long with scales, pith white and soft.

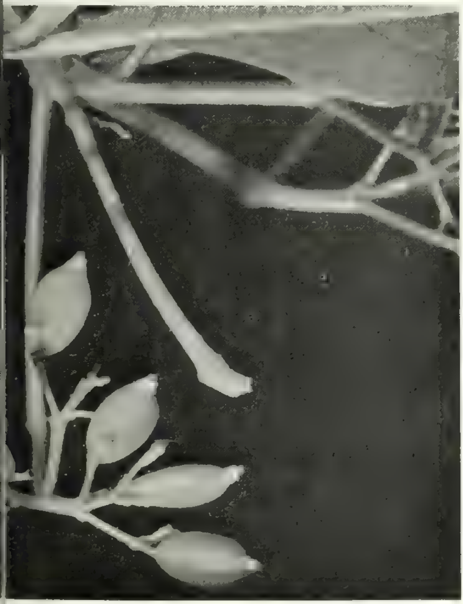
Flowers 2 to 4 inches wide. April to June.

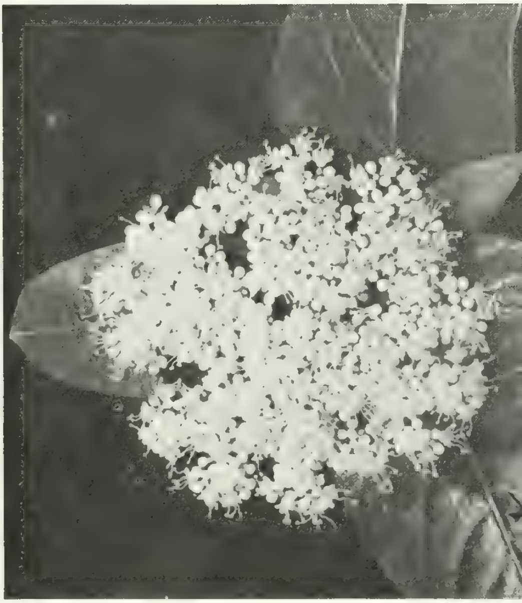
Fruit in cymes, 2 to 4.50 inches across, pink at first but glaucous-blue later. Matures in fall.

Other common names: ***witherod, bilberry, nanny-berry.***









Rusty Blackhaw

An irregularly branched shrub or tree up to 40 feet tall.

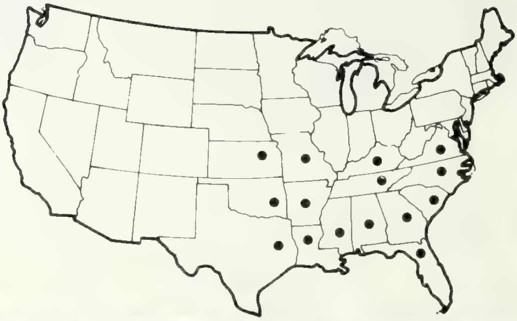
Leaves semi-evergreen in South, 1.50 to 4 inches long, 1 to 2.50 inches wide, dark green, leathery, shiny above, paler below with red hairs on veins, margin finely serrate.

Twigs reddish brown, glabrous, naked buds, covered with short rusty pubescence, leaf scars U- to V-shaped, three bundle scars; pith white, soft, 0.33 or less of total twig diameter.

Flowers in flat cymes, 2 to 6 inches across. April to May.

Fruit bluish-black in drooping clusters, 0.33 to 0.50 inch in diameter. July to October.

Other common names: ***rusty nanny-berry, southern nanny-berry, blackhaw, southern blackhaw.***



Berries

BERRIES

Berries are fruits in which the entire ovary, including the endocarp or inn ovary wall, becomes a fleshy or pulp mass enclosing one or more seeds. I species are eaten by wildlife and sev species such as grapes and tomatoe important food sources for humans. fruits are usually high in carbohydrat and low in crude protein.

The genera discussed here are bers of several family groups.

Common Persimmon/*Diospyros virginiana* L.

Leslie L. Glasgow
Louisiana State University
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Persimmon grows best on alluvial soils such as clay and heavy loams of neutral pH. It also grows on poorly drained upland sites, but fails to reach commercial size. It is a pioneer species in abandoned fields, and is also found in the understory of dense stands.

Ripe fruits of persimmon are eaten by many species of wildlife but especially by opossum, raccoon, fox, and deer. The fruits are also eaten by skunks, wild turkeys, bobwhite quail, crows, rabbits, squirrels, hogs, cattle, and many songbirds.

The seeds and fruits are generally low in crude protein, crude fat, and calcium, but high in nitrogen-free extract.

Deer browse readily on persimmon sprouts, but cattle graze them only lightly.

Optimum seedbearing age is 20 to 25 years. Seeds remain dormant overwinter and germinate in April or May. Before planting, seeds should be stratified under moist conditions for 2 to 3 months at 33 to 41°F. The seedlings develop a strong taproot, and they are difficult to transplant but when established survive under very adverse dry conditions.

Prolonged flooding during the growing season will kill young trees.

Persimmon sprouts profusely from stumps and from root collars after fire. Plants may be propagated by root cuttings and grafting.

Persimmon is frequently planted as an ornamental or fruit tree, and the fruits are occasionally used for desserts. Indians smashed and dried the pulp as an additive to many other foods.

The wood is hard, smooth, and even-textured and is particularly desirable for golf clubs and shuttles.

Other common name: eastern persimmon.

Common Persimmon

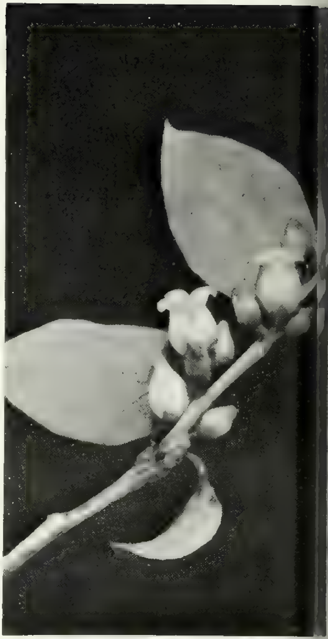
A tree or shrub usually 30 to 50 feet high, but may reach 70 feet or more on good sites. The heartwood is very hard and black; the tree is a close relative to the commercial ebony.

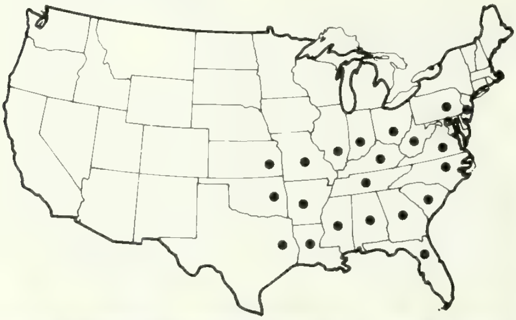
Leaves alternate, entire, thickish, ovate, smooth or nearly so, deciduous, dark green above, light below with whitish bloom, 2 to 6 inches long, 1 to 3 inches wide.

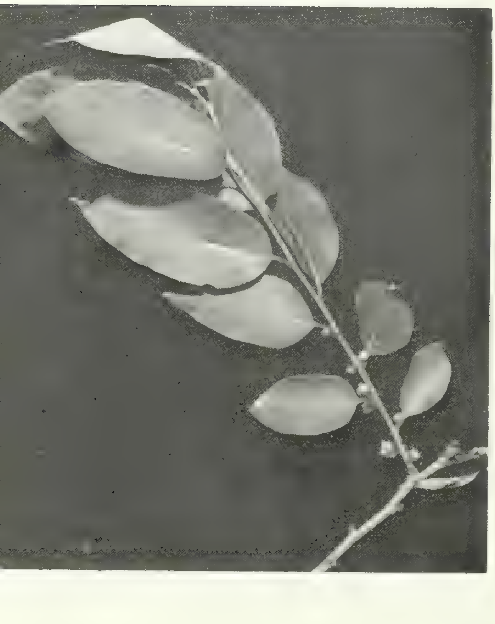
Twigs slender, slightly zigzag, lacking terminal bud, lateral buds are small, short pointed, two or three scales.

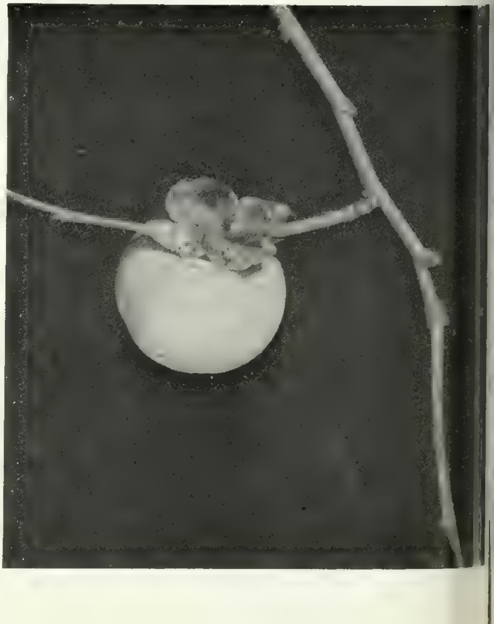
Male and female flowers on separate trees. April and May.

Fruit a rounded or slightly flattened berry becoming yellow or orange, soft, sweet, juicy at maturity, astringent when green, rots quickly after falling to ground. Seeds four to eight, flattened. September to November, may remain on tree into winter.









Eastern Redcedar/*Juniperus virginiana* L.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

The species grows on a variety of soils ranging from dry rocky outcrops to swampy land. It is frequently found on thin soils with limestone or dolomitic outcrops. Pure stands are scattered throughout its range, generally on abandoned farmlands or dry uplands. It is drought resistant and frost hardy, but cannot withstand flooding. The trees tend to make the soil more alkaline. Stockmen consider the plant a nuisance because it produces poor forage, and is an aggressive invader on overgrazed ranges or abandoned fields, often completely dominating such sites.

Juniper fruits are eaten by many wildlife species including bobwhite quail, ruffed grouse, pheasant, wild turkeys, rabbits, foxes, raccoons, skunks, opossums, and coyotes. Waxwings travel in groups to feed on the juniper berries. The fruits are moderate in calcium, high in crude fat and crude fiber. The seeds are very high in total carbohydrates.

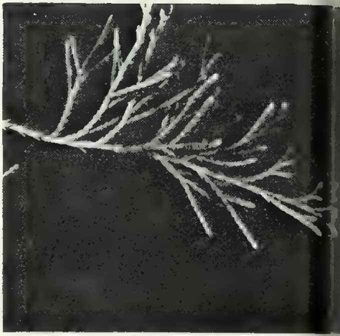
Junipers provide good nesting and roosting cover for many birds, and dense thickets make good escape cover for deer.

New growth changes from succulent green to light brown in the second year but does not become woody until the third season. The numerous low, lateral branches provide an abundance of green, but low-quality roughage that may serve as emergency food for deer in times of stress. During such times, browse lines develop on older trees, and younger ones become hedged. Tree-size plants are seldom killed, but most reproduction is destroyed.

Various methods of planting are recommended. Store seed in fruit 1 year, then clean, scarify, and sow in the fall; or store seed in fruit 1 year, then clean and stratify in peat for 100 days at 41°F and sow in the spring; or stratify outdoors in the shade from May until sowing time in the fall.

Natural reproduction mainly from seeds that birds or mammals drop on bare or partially bare soil. Growth is relatively slow and a long rotation is required to grow it to sawtimber size. Trees 20 to 30 years old are generally 18 to 24 feet tall and 2.25 to 3 inches in diameter.

Eastern Redcedar



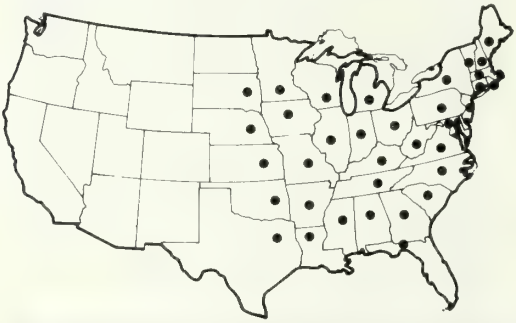
An evergreen tree 40 to 50 feet high, pyramidal crown.

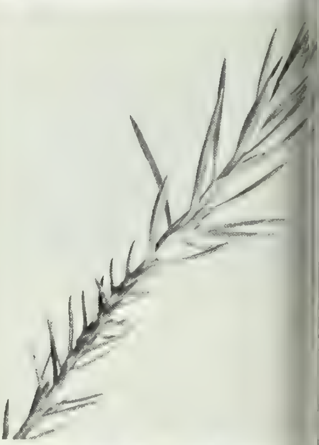
Leaves of two kinds, the scalelike are glandular, dark green, obtuse, 0.06 inch long, four ranked; the awl shaped are sharp pointed, 0.50 to 0.75 inch long.

Twigs reddish brown, round or angled.

Flowers dioecious, catkins small and terminal, male oblong, female cones globular; scales spreading, fleshy, purplish. March to May.

Fruit berry-like on staight peduncles, pale blue, glaucous, 0.25 to 0.33 inch diameter, seeds one or two ovoid, 0.12 to 0.16 inch long, smooth, shiny. September to December.





Fire is the worst enemy of redcedar. The thin bark and roots near e surface of the ground are injured by relatively light fire. The foliage, owever, does not burn easily and fires generally will not penetrate ands unless litter is heavy.

The wood is used for novelties, posts, poles, boats, woodenware, aneling, closets, chests, and pencils. The extract of cedar oil has various ommercial uses. The species is sometimes used in shelterbelt plantings d many varieties are horticulturally important.

Other common names: red juniper, redcedar, savin, and Carolina edar.

Japanese Honeysuckle/*Lonicera japonica* Thunb.

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Forest Service, USDA
Nacogdoches, Texas

Originally introduced from Asia, Japanese honeysuckle now occurs throughout the South but mainly on low moist ground along streams o on fence rows and borders of woods. Scattering of seeds by birds plus man's transplanting accounts for its wide dispersion. Plants can be established vegetatively from root and stem cuttings, rooted stolons, single plants, or even blocks of soil containing roots. The plantings need cultivation for the first year. Once established plants propagate by stolon which on open, moist sites spread as much as 15 feet in a year.

The fruits are eaten by many kinds of songbirds, and by wild turkeys, quail, and white-tailed deer. Honeysuckle browse is relished by deer. The dense network of vines and leaves produce abundant forage that is readily eaten the year round, but primarily in winter. Frequently the outer stems and leaves are browsed very closely, but the tangled ma of old stems forms a barrier against complete removal. New shoots arising from old growth are a continuous source of nutritious forage.

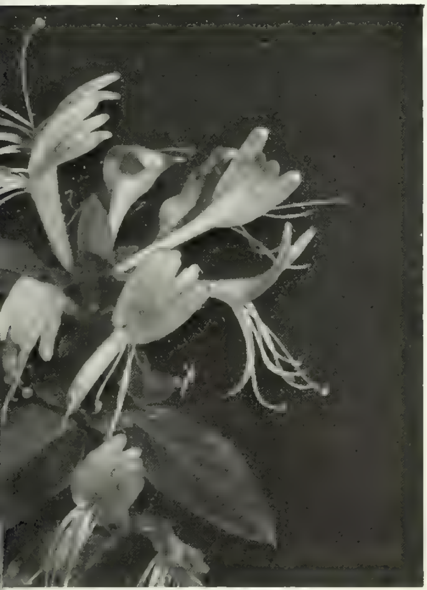
Its ease of propagation and high vigor make Japanese Honeysuckle valuable as game food but a nuisance in timber management. The most difficult task is confining it to specified areas. Uncontrolled, the species overwhelms and strangles low-growing plants and trees, including some that are valuable to wildlife. In open areas it quickly covers the ground and severely restricts forest tree regeneration. It competes with young timber in 10 percent of the forest land from Georgia to Maryland. In timber stands of pulpwood size and larger, shading and needle cast keep the species in check until the trees are harvested.

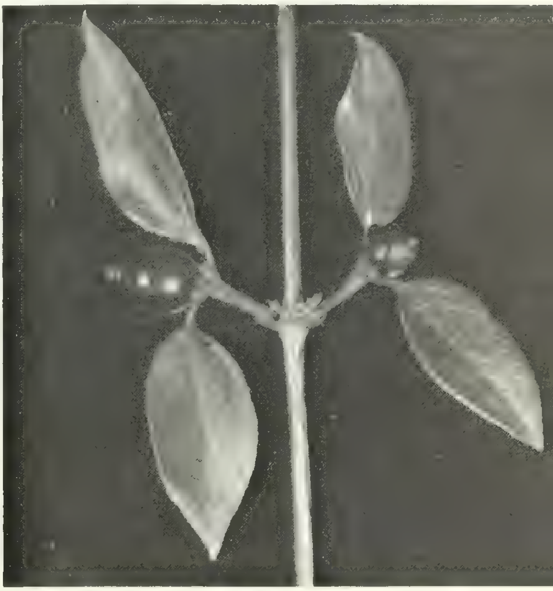
In a study near Nacogdoches, Texas, fruit yields were 222 grams (ovendry weight) for plants growing in the open and 11 grams for plants growing in the woods. Fruits persisted on plants through the winter. The pulp/seed ratio ranged from 1:0.27 to 1:0.45. The fruits are low in crude fiber, high in nitrogen-free extract, and moderate to high in phosphorus and calcium.

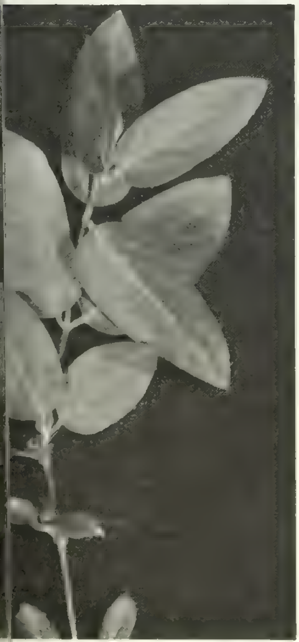
Honeysuckle makes good winter forage for cattle and provides excellent cover for quail, turkey, songbirds, and small mammals.

he species is often seen as an ornamental.

ther common names: honeysuckle, southern honeysuckle, white suckle, and Chinese honeysuckle.







Japanese Honeysuckle

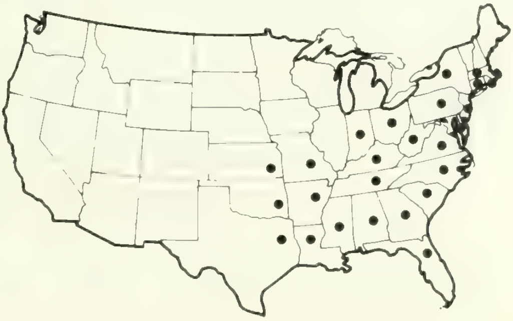
A trailing or twining woody vine.

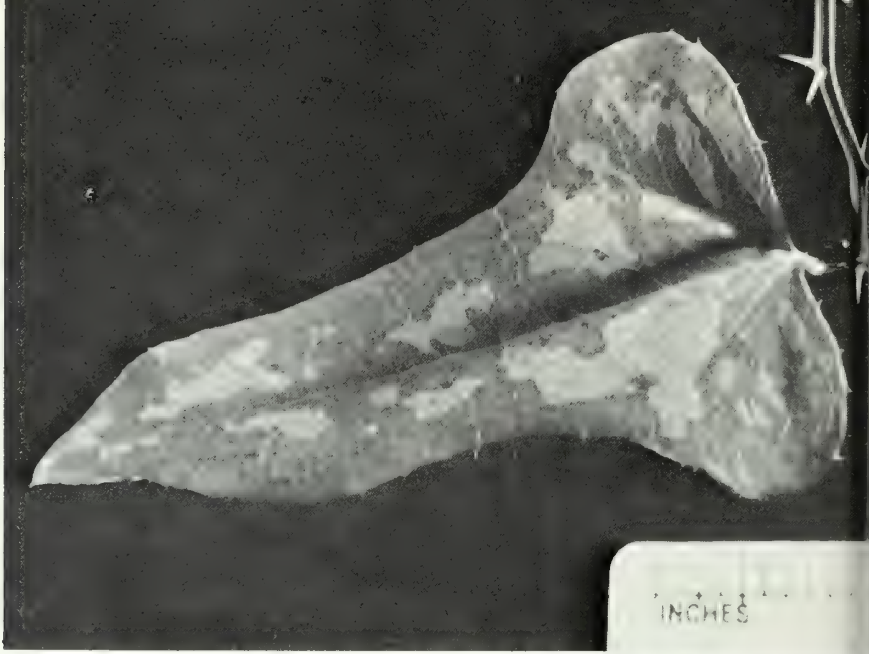
Leaves semi-evergreen, entire, hairy, 1 to 3 inches long; 0.50 to 0.75 inch wide.

Stem bark shreddy, twigs reddish-brown, hairy, hollow in center.

Flowers fragrant, in pairs from leafy bracts. Corolla 0.50 to 1.50 inches long, white or pink, later yellow. June to August.

Fruit a black pulpy berry, 0.16 to 0.25 inch long. September and October.





Saw Greenbrier

A straggling to climbing vine.

Leaves tardily deciduous, usually thick and often blotched with white, 1.50 to 4.50 inches long, 0.70 to 3 inches wide, margins and main veins usually prickly.

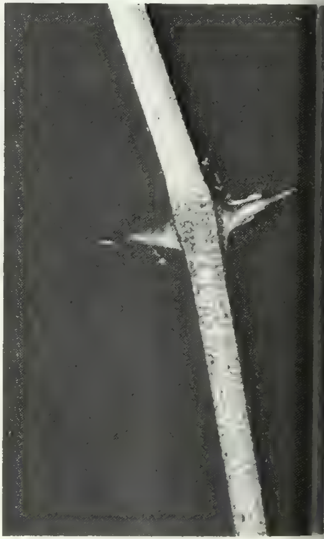
Cane four-angled or round, zigzag in upper reaches, main branches with stiff, flattened, black-tipped spines clustered at the nodes.

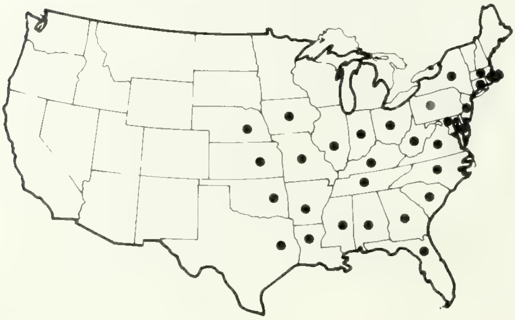
Flowers April to June.

Fruit black with a bloom, about 0.25 inch long, single seed, stretchy. October to November.

Underground stems are woody tubers, single or in a compound mass up to 6 inches across. Roots with short, resinous-tipped spines.

Other common names: ***China brier, bullbrier, fiddle-leaf greenbrier, and sawbrier.***





reenbriers/*Smilax* spp.

hil D. Goodrum
.S. Fish and Wildlife Service
acogdoches, Texas

reenbriers are a group of thorny, woody vines, all more or less alike appearance. They retain leaves most of the year. The flowers are pale een and very small.

The five species discussed here are widely distributed in both dense id cutover forests, in swamps and abandoned fields, and along fence ws. They tolerate shade but maximum growth of twigs and production fruit is obtained from plants growing in the open.

The fruits are eaten by ruffed grouse, wild turkey, bobwhite quail, y at least 38 species of songbirds, and by mammals such as white-iled deer, black bear, opossum, raccoon, squirrels, and rats.

The fruits of greenbriers are moderate to low in crude protein, iosphorus, and calcium, moderate in crude fat, and high in nitrogen-ee extract.

Common greenbrier (*S. rotundifolia* L.), the most widely stributed species, is especially abundant in low, damp flatwoods. aurel greenbrier (*S. laurifolia* L.), is largely confined to bay and swamp argins and banks of marshy streams, but occasionally is found on pland sites. Lanceleaf greenbrier (*S. smallii Morong*), is most abundant the lower Coastal Plain along edges of small streams, swamps, and tches in well drained but not dry soil. Cat greenbrier (*S. glauca Walt.*), id saw greenbrier (*S. bona-nox* L.), grow in a variety of soils and oisture conditions.

Greenbriers are present in all stages of plant succession. Rhizomes ay persist for years, even when the canes have been killed by fire or disturbance of the ground. Disturbance may scatter the rhizomes and us multiply the plants. Canes live from 2 to 4 years and produce owers after the first year, usually from annual shoots on the upper arts of the cane.

Saw greenbrier plants bear fruit annually but usually in small nounts. Some fruit persists through most of the winter. The average ulp to seed ratio is 1:1.59.

Greenbriers are considered by many to be the most important oup of deer food plants in the South. The fast-growing green canes

Cat Greenbrier

A slender, climbing vine.

Leaves tardily deciduous, 1.50 to 4 inches long, 1.25 to 3 inches wide, white or glaucous on the underside.

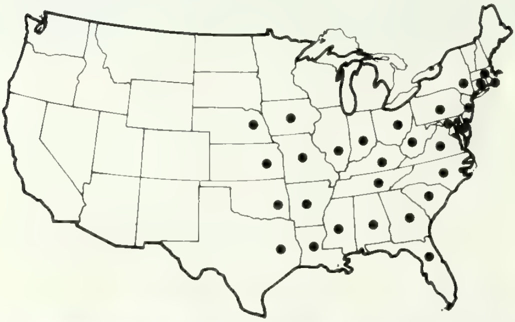
Cane green or mottled brown, lower part thickly set with slender, slightly recurved, needle-like spines between the nodes.

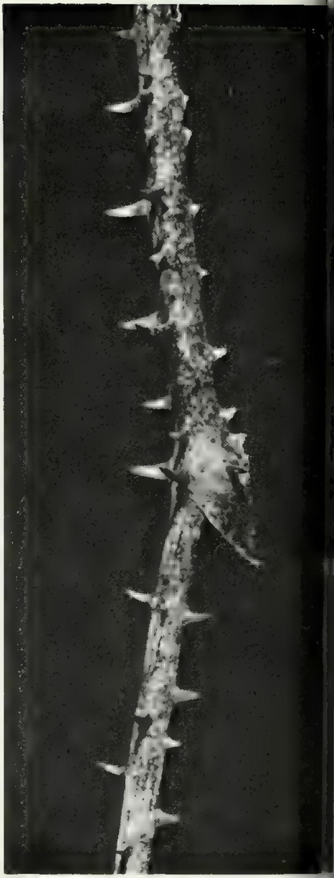
Flowers May to June.

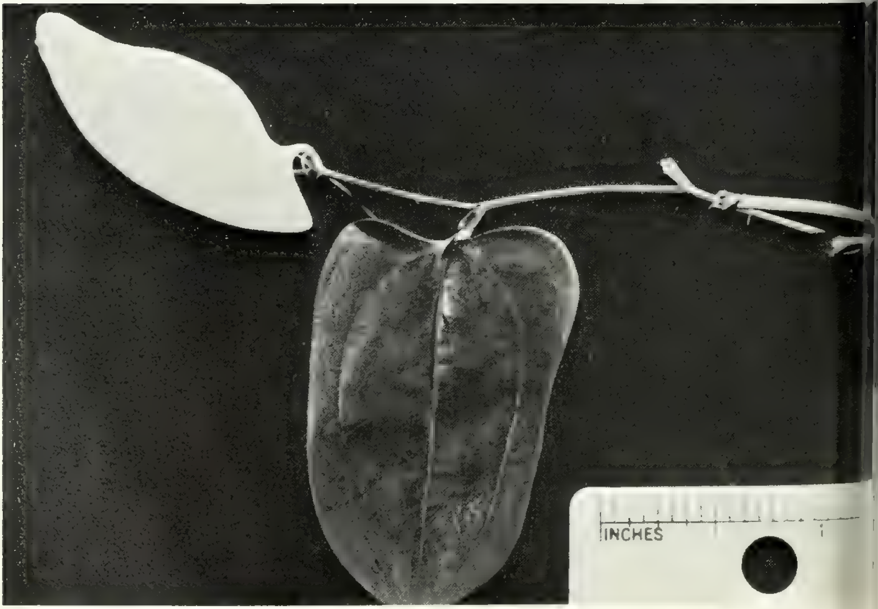
Fruit black with a bloom, ripens in first year. Seeds two or three.

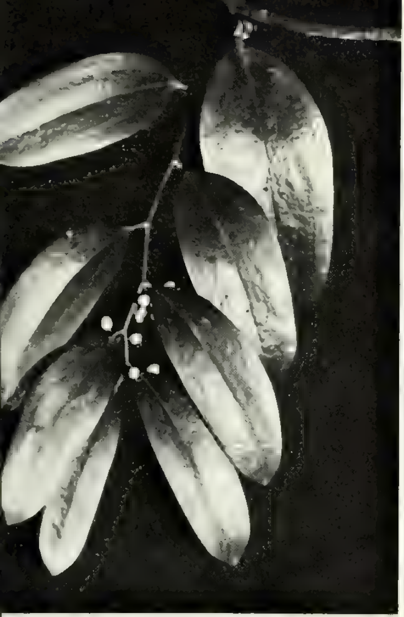
Underground stems consist of tubers and rhizomes. Tubers 0.50 to 2 inches thick, not spiny; rhizomes with small prickles between nodes.

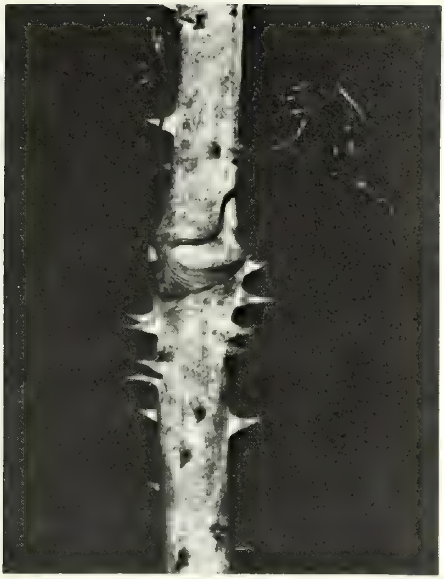
Other common names: ***sawbrier, wild sarsaparilla, stretch greenbrier, catbrier,*** and ***glacous-leaf greenbrier.***

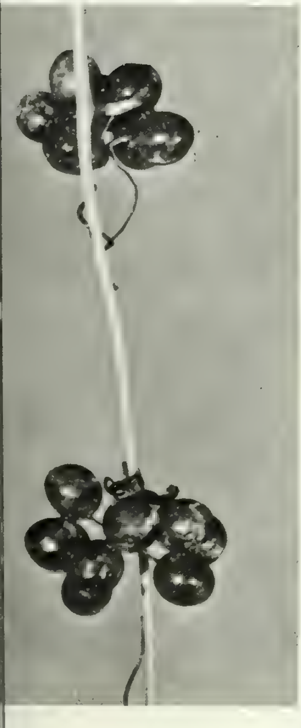












Laurel Greenbrier

A stout, high-climbing vine.

Leaves 2 to 6 inches long, 0.50 to 1.50 inches wide, evergreen, thick and leathery, with three prominent veins.

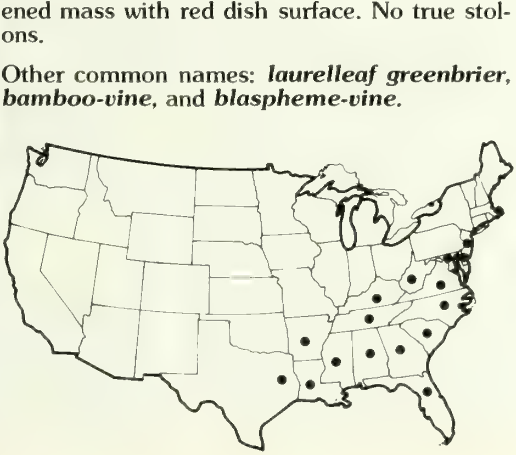
Cane mostly round, up to 0.50 inch thick, spines abundant on lower part, flattened but stout, up to 0.50 inch long. Usually no spines on joints.

Flowers greenish-white. July and August.

Fruit shiny black, in clusters of 5 to 25. Matures in October, during second year after flowering.

Underground stems a hard and knotty thickened mass with red dish surface. No true stolons.

Other common names: ***laurelleaf greenbrier***, ***bamboo-vine***, and ***blaspheme-vine***.



and tender shoots are very palatable, and the leaves are eaten all year. Greenbriers were among the most heavily grazed of 73 browse species in an east Texas pine-hardwood forest.

The growing habit and fleshy root system make greenbriers very tolerant to deer browsing. Rhizomes usually produce new canes annua These canes grow quickly, but if the tips are nipped off new branches form at one or several remaining nodes. Thus, browsing helps in maki the new growth available.

Greenbriers withstand heavy grazing and browse use, especially cat greenbrier because it tends to form a dense hedge of stiff stems. About 50 or 60 percent of the annual growth of greenbriers may be eaten without mortality of roots.

Cattle compete with deer for the stems and leaves.

When canes grow out of reach of deer, forage conditions can be improved by a prescribed burn. The regrowth is immediately available and has more crude protein than older stems.

The young stems are relished by swamp rabbits.

Common greenbrier may overburden young trees, but the loosely twining vines of other species do not dominate the ground completely enough to inhibit the growth and development of tree seedlings. The spiny stems are a nuisance to woods workers.

Greenbriers can be propagated from rootstocks, but canes may not appear until the second year after planting. Lanceleaf greenbrier will not spread from the planting point except by dissemination of see because it has tubers instead of rhizomes.

Underground parts of laurel and lanceleaf greenbriers are high in starch content and were valued by the Indians as food. Large tubers are eaten by hogs. The vines are extensively used for decoration. The new leaves make a good salad and the young shoots are eaten as gree s

Common Greenbrier

A tough, stout woody vine climbing up to 20 feet and forming tangled thickets.

Leaves 2 to 6 inches long, 1 to 6 inches wide, mostly round and smooth, tips abruptly pointed, green both sides, shiny beneath. Tardily deciduous.

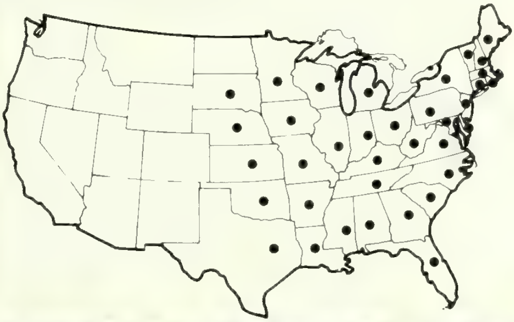
Cane round or four-angled, green at all ages. No spines on nodes.

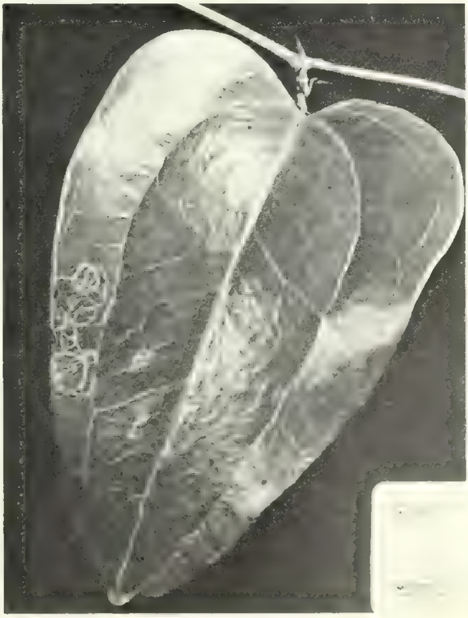
Flowers March to May.

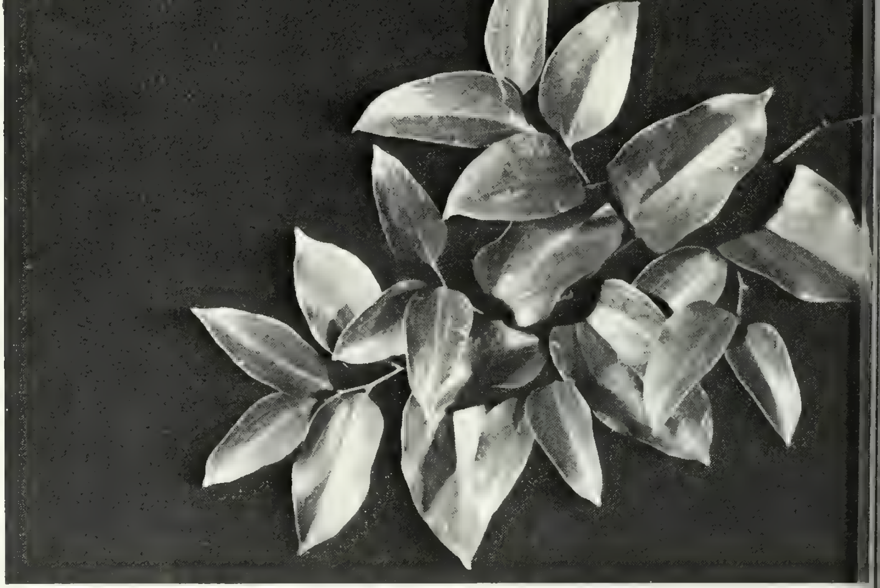
Fruit black with a bloom, matures in one year. Seeds two to three. September to October.

Underground stems long, slender, and glabrous. No tubers.

Other common names: ***common bullbrier, horsebrier, sawbrier, Devil's-hop-vine,*** and ***roundleaf greenbrier.***







Lanceleaf Greenbrier

A stout high-climbing vine that grows up for many feet without branching.

Leaves 2 to 5 inches long, 0.75 to 2 inches wide, mostly lance-shaped, deep green and shining on upper surface, five veins, rarely seven. Evergreen. Young leaves are smaller than adult leaves and have minute blunt teeth on margins.

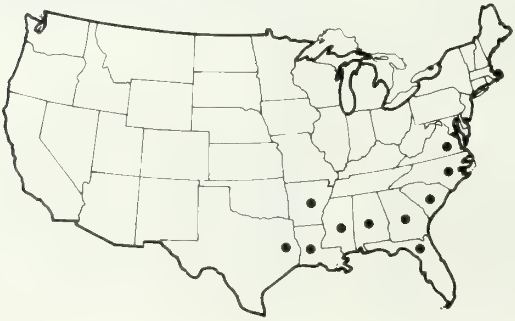
Cane dark-greenish or reddish-brown, splotched with gray. Spines few and scattered, flattened, often recurved, about 0.20 inch.

Flowers jasmine-like odor. April to July.

Fruit up to 0.25 inch thick, in clusters, maroon to blackish-red when ripe, usually two seeds. Matures second year in June.

Underground stems tuberous, may reach a length of 2 feet and weigh up to 16 pounds; young tubers firm like an Irish potato.

Other common names: ***thornless smilax, coral greenbrier***, and ***bamboo-vine***.



Blueberries/*Vaccinium* spp.

Edward E. Dale, Jr.
University of Arkansas
Fayetteville, Arkansas

Ralph Hughes
Forest Service, USDA
Fort Myers, Florida

Blueberries are a widely distributed group of shrubs or small trees. The various subdivided genus *Vaccinium* is not well understood taxonomcally. Many hybrids occur among species that have overlapping geographic ranges. Blueberries have somewhat four-angled branchlets; alternate, evergreen or deciduous leaves; and white, greenish, or rose-colored flowers that are generally drooping and somewhat bell-shaped. The fruit is a globose, four- to five-celled berry with a persistent calyx on the flattened end.

Tree sparkleberry (*V. arboreum* Marsh.), is found in sandy or rocky woods, thickets, and clearings. It is one of the few blueberries that grows n neutral or slightly alkaline soils.

Dryland blueberry (*V. vacillans* Torr.) and common deerberry (*V. stamineum* L.) are usually found in colonies, often in nearly pure stands. They generally grow on well drained, acid soils in dry, open pine or oak woods, along rocky ledges, and occasionally in abandoned fields.

Ground blueberry (*V. myrsinites* Lam.) is common in wet sandy soils in uncultivated places. In Florida it is the most widespread and abundant of the wild blueberries. It responds favorably to range burning. No fruit is produced the season in which the burning is done, but a substantial increase usually occurs the following year. The pruning action of fire generally assures regular crops of berries. In south Georgia, sprouts appear in early March after a January burn and attain a height of about one foot by midsummer. Plants usually occur in large colonies. Ground blueberries persist beneath fully stocked stands of pine, but plants growng in low light intensities produce fewer flower buds and fruits than hose growing in the open. Maximum vegetative growth and flower bud ormation seem to occur in full sunlight.

The sweet juicy fruits of blueberries are relished by many species of wildlife. They are among the most important summer and early fall

Tree Sparkleberry

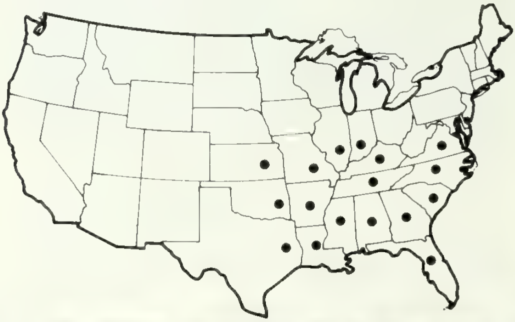
A shrub or small crooked tree up to 30 feet tall.

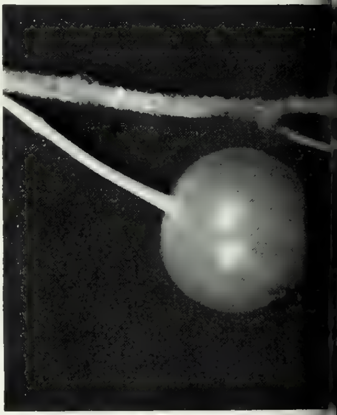
Leaves 1 to 3 inches long, tips rounded, margins turned inward, deciduous, becoming evergreen southward.

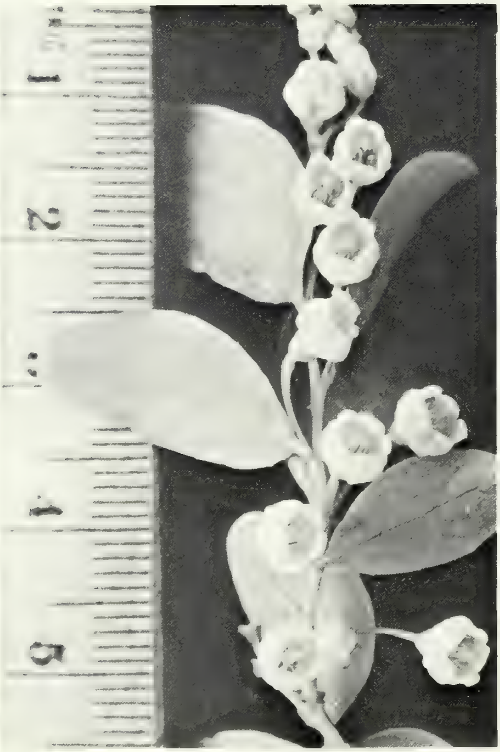
Flowers white on long slender stalks in loose, leafy-bracted clusters.

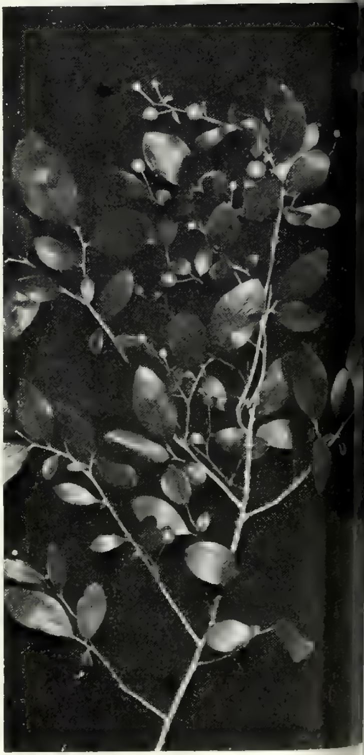
Fruit black, about 0.23 inch in diameter, with dry pulp and hard stone-like seeds. Ripens in August to October but often persistent over winter.

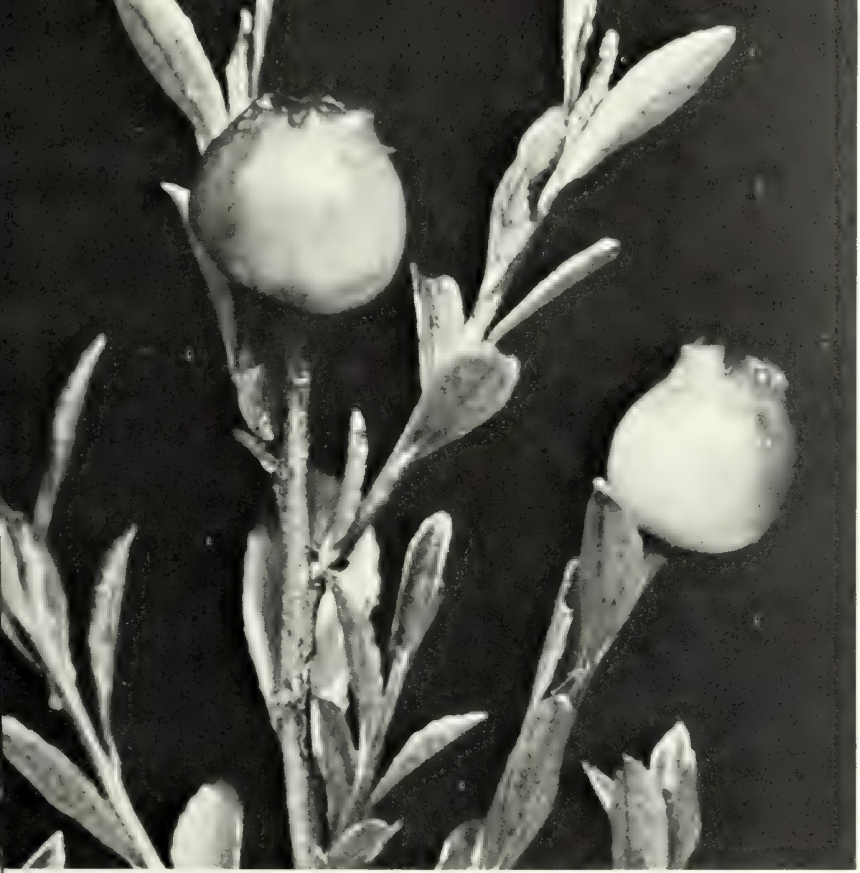
Other common names: ***farkleberry, whortleberry, tree-huckleberry, winter-huckleberry.***











Ground Blueberry

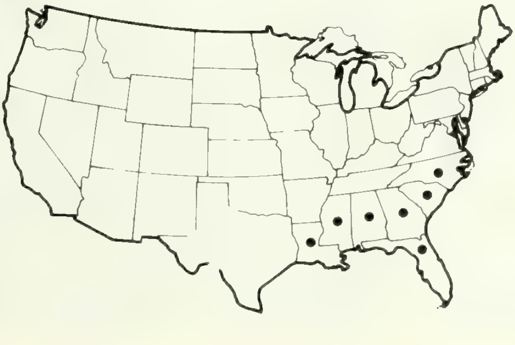
A low, much-branched shrub up to 3 feet tall.

Leaves 0.30 to 0.80 inch long, leathery, evergreen, underside usually glandular.

Flowers white to pink in umbel-like clusters.

Fruit dark, sometimes covered with bloom, about 0.23 inch in diameter. May.

Other common names: ***evergreen blueberry, Florida evergreen blueberry.***



foods for ruffed grouse and are a preferred summer food for wild turkey. They are eaten by bobwhite quail and by songbirds, particularly the scarlet tanager, robin, cardinal, bluebird, and thrasher. Blueberries comprised about 2 percent of the quail diet in June, and huckleberries and blueberries, 19 percent of the quail food in July in one south Georgia study. Blueberries are a favorite of black bear and are eaten by deer and by many small mammals such as chipmunks, rabbits, foxes, and raccoons. The buds and winter foliage of blueberries are also eaten by ruffed grouse.

The fruits are low in crude protein and phosphorous, but high in nitrogen-free extract.

In some areas blueberry foliage is unpalatable; in others it is choice deer food. Dryland blueberry ranks as a second- or third-choice plant in the western Gulf Coast. In the flatwoods and pine-oak sites of Florida, utilization of several blueberry species ranged from 10 to 38 percent.

A summer survey in the Choccolocco Wildlife Management Area of northeastern Alabama, where dryland blueberry comprised 72 percent of all shrubs, showed that 54 percent of the annual growth was removed. Browsing was greatest in April and May, but continued during winter. Availability and utilization were highly variable in different years.

Some domesticated animals eat young twigs and leaves. The browse is of negligible value to sheep and cattle.

Blueberries are eaten extensively by humans. Several large-fruited species are cultivated. Others are used as ornamentals. The hard and very close-grained wood of tree sparkleberry is sometimes used for tool handles.

The blueberries in general may be propagated vegetatively or from seed. Standard procedure for seed is to clean it from the fruits in a household blender and store dry in vials with cork stoppers in an ordinary refrigerator at a temperature of about 40°F until used. Seeds may be sown on moist, shredded sphagnum moss in flats, held in a moist seed pit over winter, and then brought into a greenhouse for germination. Handled this way, the seed of commercial blueberry varieties held in storage 1-13 years gave fair to very good germination rates.

In commercial production, blueberries are usually propagated by means of hardwood cuttings. These are commonly taken during the lat winter and inserted in the planting medium in the spring.

Ground blueberry has long been valued as an ornamental because of its small evergreen leaves, attractive flowers, and fruits.

Common Deerberry

Diffusely branched shrub rarely more than 6 feet tall.

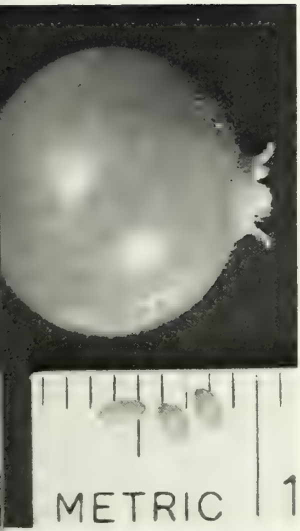
Leaves rounded at base, 1.20 to 3.50 inches long, deciduous.

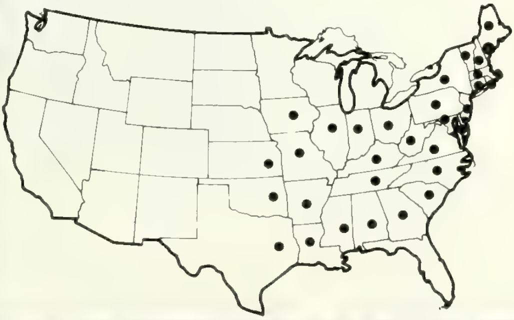
Twigs pubescent when young; bark becomes platy and fissured on old plants, leaf scars small, half round to circular with one dot-like bundle scar.

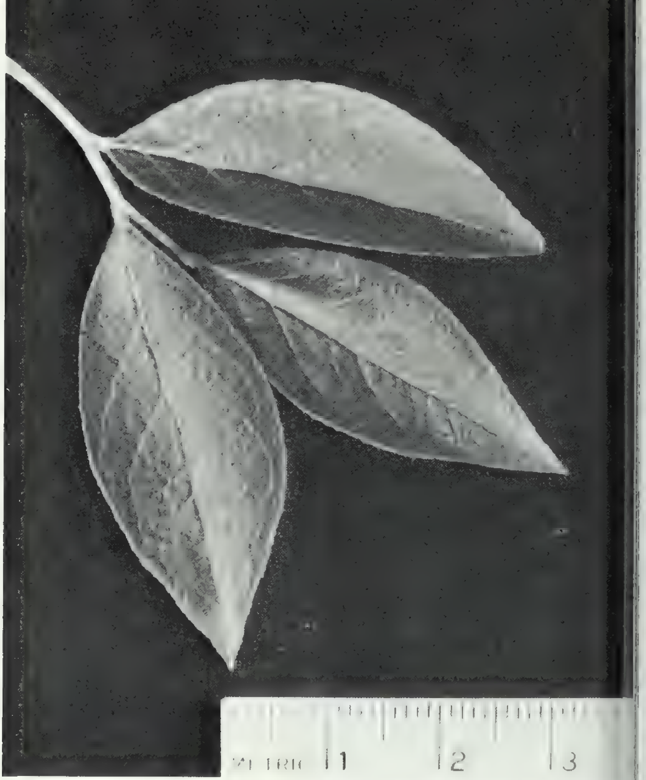
Flowers greenish-white to purple on specialized flowering branches subtended by leafy bracts. April to June.

Fruit green or yellowish, about 0.40 inch in diameter, usually drops after maturity in late July to September.

Other common names: ***squaw huckleberry, buckberry.***







Dryland Blueberry

A low shrub 0.50 to 3 feet tall.

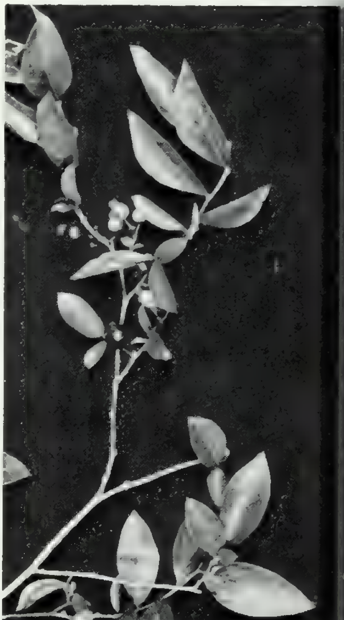
Leaves V-shaped at base, 0.75 to 1.75 inches long, deciduous, leathery when mature.

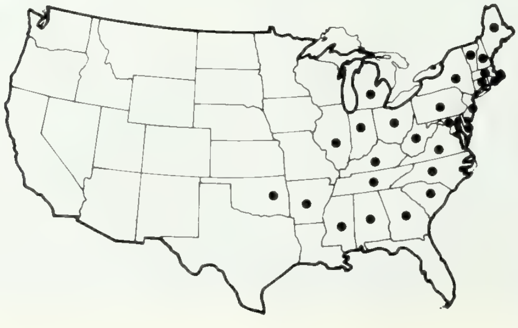
Twigs brown or greenish, often crooked.

Flowers greenish to purplish on ends of branches or from old axils, appear before leaves are fully expanded.

Fruit blue to black, 0.20 to 0.30 inch in diameter. June to September.

Other common names: ***Blueridge blueberry, low bilberry, lowbush blueberry, sugarhuckleberry.***





Grapes/Vitis **spp.**

A. B. Massey
Virginia Polytechnic Institute and State University
Blacksburg, Virginia

Grapes are important food and cover plants for a variety of birds and mammals. The vines climb over brushy thickets, fences, woodland borders, and high into trees. Grapes grow best in moist fertile soils and are commonly found along stream banks. They are relatively intolerant to shade.

The plants are usually dioecious, but some have perfect flowers. The fruits are fleshy berries. Leaves are simple. The vines usually climb by the coiling of tendrils.

The fruits of grapes are relished by many songbirds, ruffed grouse, and several mammals such as black bear, white-tailed deer, and raccoons. Fruits are especially important to wild turkeys and grouse, and these birds tend to congregate where grapes are abundant during the fall and winter. Fruits are also eaten by bobwhite quail, wood ducks, and squirrels, and to a lesser extent by red foxes. Young canes and occasionally the dried leaves are eaten by deer. The abundant foliage provides good wildlife cover. The shredded bark on most species is a source of material for nests. The plants are widely cultivated for their delicious fruits, and are readily propagated by cuttings, grafting, or layering.

In summer, grape stands provide excellent escape and nesting cover for songbirds.

The fruits are generally low to moderate in crude protein, moderate in phosphorus, and high in nitrogen-free extract.

Trees with grape vines in them appear to be preferred sites for leaf nests of gray squirrels.

Four of the most widespread grapes are described here.

Summer grape (*V. aestivalis* Michx.) grows on warm sandy soil in dry woods, thickets, and along roadsides. It is most abundant in the upper Piedmont and mountains. Fruits remain on the plant, slowly drying to a raisin-like consistency, and are available into winter. The plant produces good fruit crops in most years; however, the yields fluctuate greatly between years.

Sweet winter grape (*V. cinerea* Engelm.) grows in moist alluvial soils along streams, thickets, and bottomlands.

Summer Grape

A vigorous vine, climbing by tendrils.

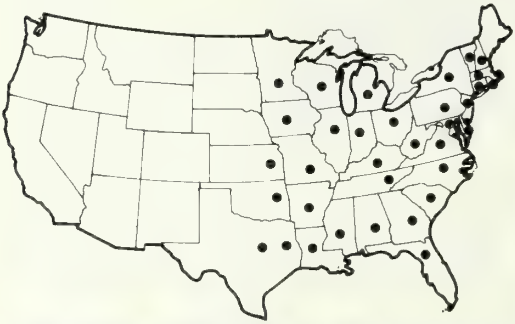
Leaves 2 to 8 inches long, margin irregularly toothed or lobed, smooth, dull, and glabrate above, lower surface rusty tomentose.

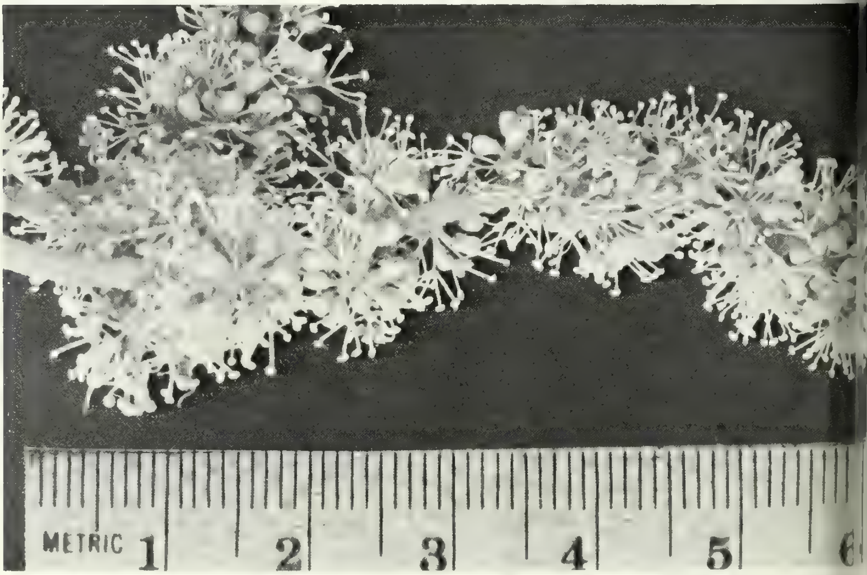
Twigs reddish-brown, wooly at first, then glabrous, nodes swollen, 0.50 to 0.12 inch thick, bluish-gray waxy bloom, buds rusty brown pubescent underneath scales, pith soft, brown, interrupted at nodes, lenticels uncommon, leaf scars triangular to half round, bundle scars indistinct.

Flowers small, clustered in a slender, loose panicle. May to July.

Fruit 0.20 to 0.50 inch diameter, dark blue to black, two to four seeds. September to October, but persistent into winter.

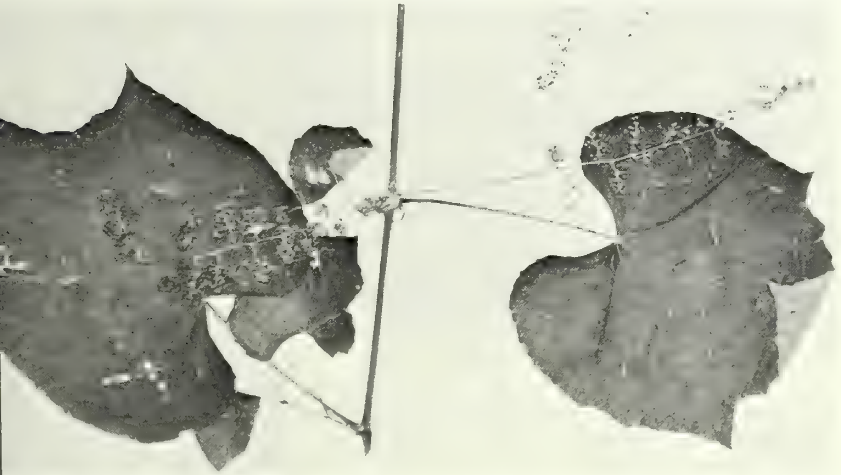
Other common names: ***pigeon grape, bunch grape.***





uscadine grape (*V. rotundifolia* Michx.) grows in moist, shady ons, and in high bottomlands where land is well drained.

rost grape (*V. vulpina* L.) grows along river banks, bottomlands, ch thickets. It endures cold better than most other grapes, but it ands long summer heat and drought poorly.



Sweet Winter Grape

A lax, high-climbing vine attaining large size.

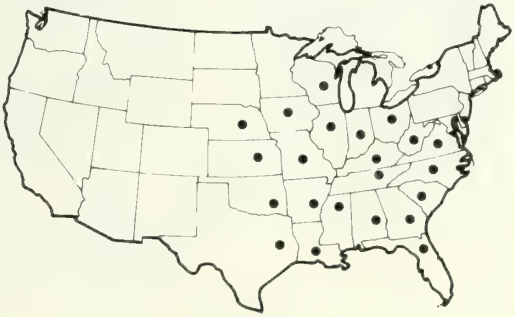
Leaves 4 to 8 inches long or broad, deep basal sinuses, margin unlobed, upper surface at first with thick, white tomentum, dark green, diminishing at maturity, lower surface densely felty.

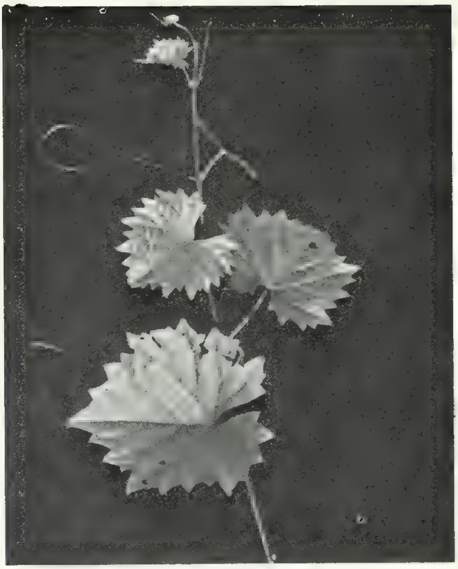
Twigs angled when young, densely white-felty, pale brown to gray, nodes enlarged.

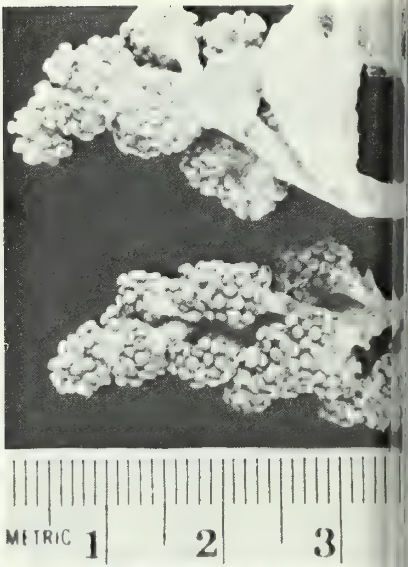
Flowers in open panicles. June to July.

Fruits numerous, 0.16 to 0.33 inch diameter, black or purple, slight bloom, tough skin, one to three seeds. September to October.

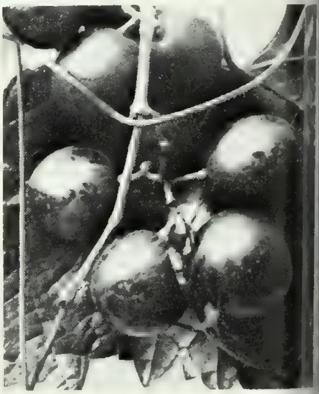
Other common names: *pigeon grape, graybark grape.*







Muscadine Grape



A slender high climbing vine lacking the shreddy bark of most grapes.

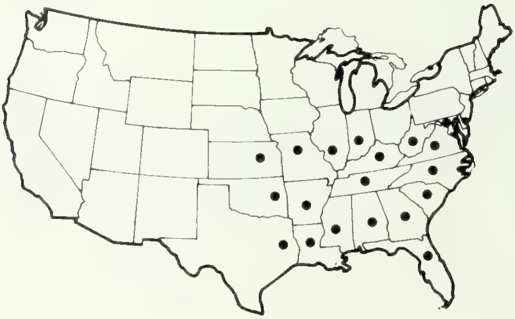
Leaves seldom lobed, margin coarsely serrate, thick, firm, upper surface glabrous, dark green, lustrous, lower surface paler, glabrous, blade 1.75 to 5 inches long, 2 to 4 inches wide.

Twigs green to reddish brown, warty, tendrils simple, leaf scars alternate, buds rusty brown underneath scales, pith firm, light tan, lenticles profuse and lighter than twigs, leaf scars half round to circular.

Flowers in small, dense, short-branched panicles. May and June.

Fruit purplish-black soon after ripening, borne in clusters, 0.33 to 1 inch diameter, skin tough, flesh thick and tough. August.

Other common names: ***Southern fox grape, bullace grape, bullet grape, bull grape, scuppernog.***



Frost Grape

A vigorous high climbing vine, attaining a length of 10 to 30 feet or more, trunk sometimes 1 to 2 feet thick.

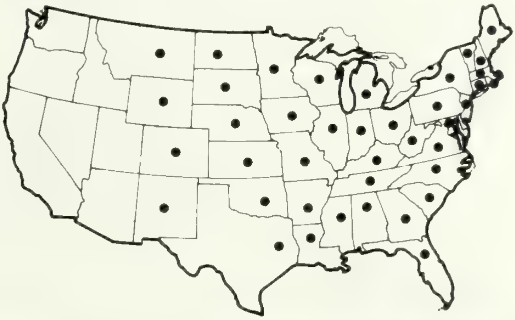
Leaves 3 to 5 inches long, broader than long, about one-third folded toward upper surface, teeth on margin large, smaller teeth between, both surfaces smooth, upper dark green, below paler.

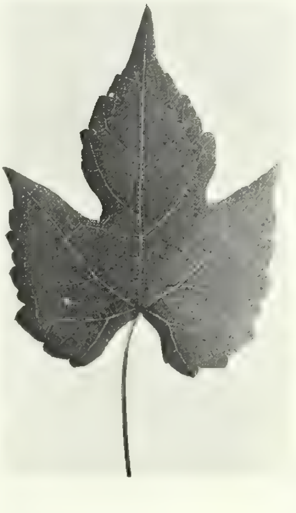
Twigs pubescent when young, reddish, becoming glabrous, clear green, nodes slightly swollen and a little bent, thin diaphrams, large pith.

Flowers in clusters 3 to 5 inches long. May to June.

Fruit persistent, 0.25 to 0.33 inch diameter, black (rarely white), thin skin, two to four seeds. September to October.

Other common names: ***winter grape, chicken grape.***





Nuts

NUTS

Nuts are hard indehiscent, one-celled, and one-seeded fruits. They are commonly referred to as hard mast. The seed, or kernel, is relished by wildlife, and in some cases, such as pecan, by humans. In many species the nuts are a concentrated source of crude fat, in some the nuts are high in crude protein, and in others nuts are high in nitrogen-free extract.

Most of the nut-bearing genera are in the Juglandaceae and Fagaceae families.

American Hornbeam/*Carpinus caroliniana* Walt.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

This very tolerant, small crooked understory tree grows in rich woods and swamps. Although of secondary importance as wildlife food, the nutlets, catkins, and buds are eaten by several kinds of birds, includin ruffed grouse, ring-necked pheasant, and bobwhite quail. The seeds, bark, and wood are consumed to some extent by rabbits and beavers. The foliage is eaten by deer, but is low-choice.

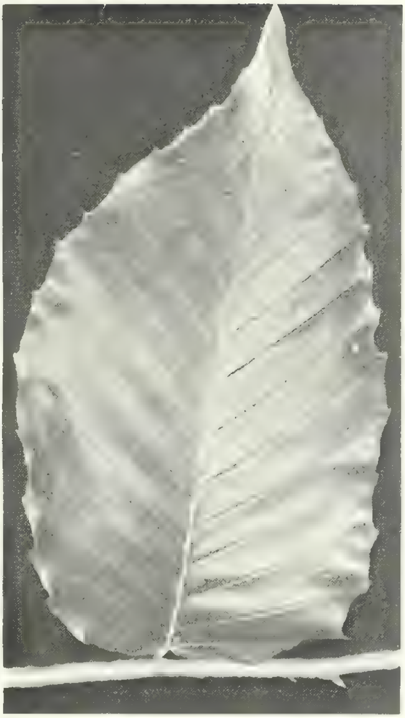
Hornbeam is especially important as an understory species for gr squirrels in bottomland hardwood forests. The fruit is eaten in some areas by wild turkeys.

Occasionally the species is planted as an ornamental, mainly for its orange and scarlet leaves in autumn. Germination is rather low for stored seed, but if collected slightly green in August, germination rate are good. Seed should be planted in rich moist soil. The tree grows slowly and the maximum seed-bearing age is 25 to 50 years.

The seeds are moderate in crude protein and phosphorus conte high in crude fiber, and low in calcium.

The wood may by used for such products as golf clubs, handles, fuel, mallets, and wedges.

Other common names: blue beech, water beech, and ironwood.



American Hornbeam

A small crooked understory tree, up to 35 feet tall.

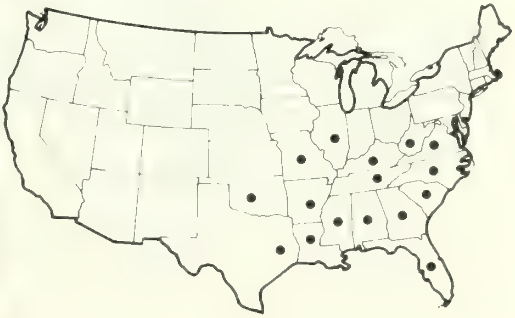
Leaves oblong to narrowly oblong-ovate, 1 to 3 inches long, wedge or heart shaped, bluish green, deciduous.

Twigs alternate, slender, zigzag, gray or red.

Bark thin, bluish gray, sometimes blotched.

Flowers green below, red above. April to June.

Fruit a nutlet about 0.33 inch long, ovoid, acute, borne at base of a three-lobed bract, many together forming loose pendent clusters 3 to 6 inches long. August to October.



***Hickories/Carya* spp.**

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

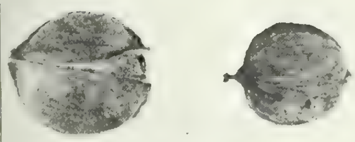
Hickories are slow-growing, deciduous trees that live as long as 250 years. In spring the scaly buds usually put forth both male and female flowers—the male below and the female above the odd-pinnate leave The hard, bony nut is surrounded with a thick husk that separates int four valves. Nuts ripen and fall September to November.

Hickories are a source of food to many kinds of wildlife. The nut are relished by squirrels, and may be eaten even before ripening. Nut and flowers are eaten by the wild turkey and several kinds of songbir Apparently the nuts can be crushed by gizzard action in the turkey. The nuts and bark are eaten by black bears, foxes, rabbits, and raccoo Small mammals eat the nuts and leaves. White-tailed deer make ligh use of the leaves, twigs, and nuts.

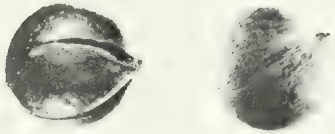
The kernel portion of hickory seeds is exceptionally high in crud fat—up to 70 and 80 percent in some species. Crude protein, phosphorus, and calcium contents are generally moderate to low. Crude fiber is very low.

For propagation purposes nuts should be stratified over winter i a mixture of sand and peat or in sandy loam and protected from free ing by covering with compost, leaves, or soil.

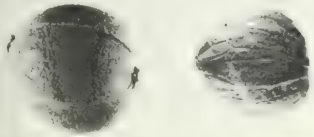
YA HICKORY



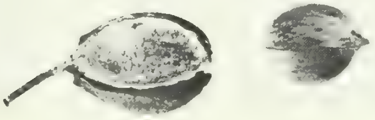
quatica water hickory



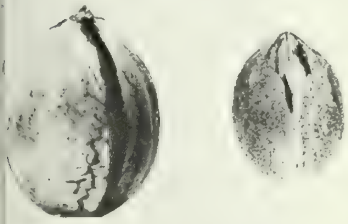
C. cordiformis bitternut hickory



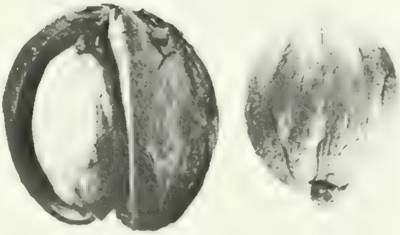
glabra pignut hickory



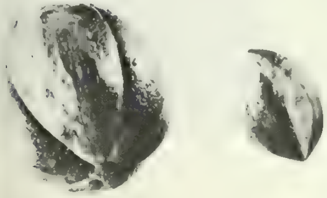
C. myristicaeformis nutmeg hickory



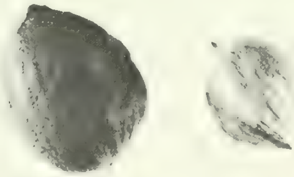
llinoensis pecan



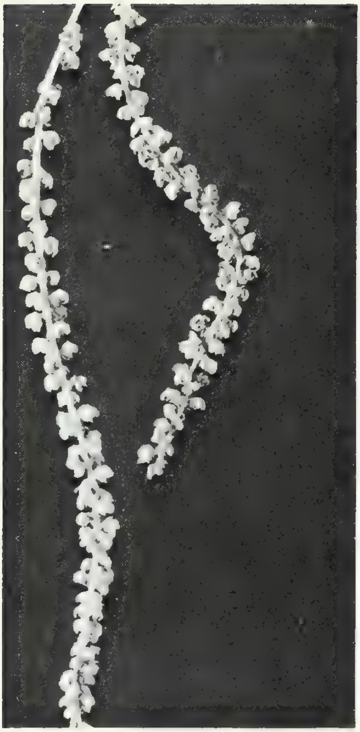
C. laciniosa shellbark hickory

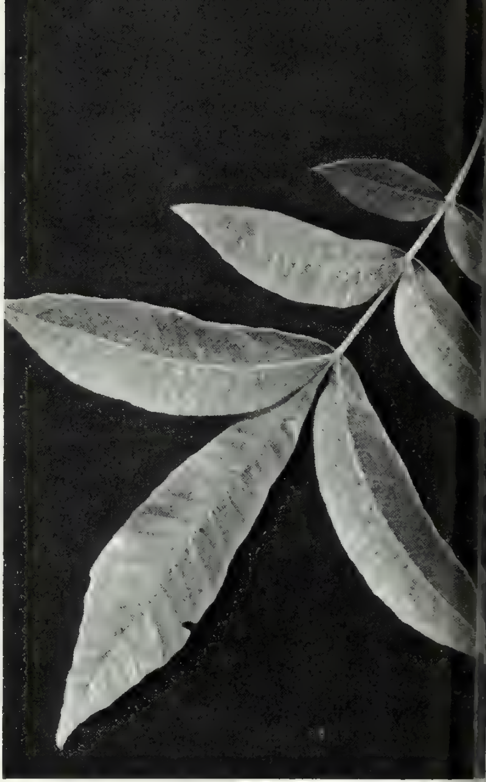


vata shagbark hickory



C. tomentosa mockernut hickory





Water Hickory

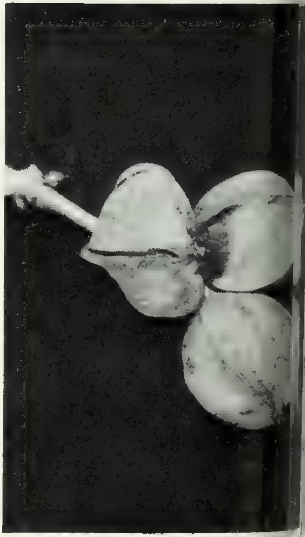
A water-loving tree attaining a height of 100 feet with an irregular narrow crown.

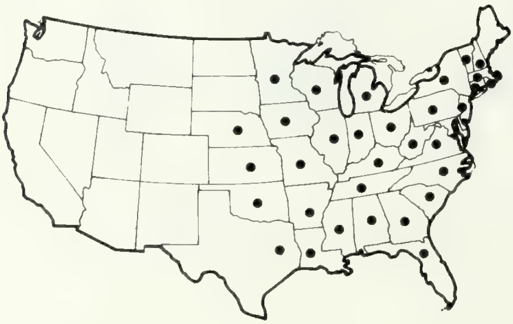
Leaves alternate, deciduous, dark green, 9 to 15 inches long.

Twigs reddish brown or gray, tomentose at first, glabrous later, lenticels pale.

Flowers in catkins, staminate 2.50 to 3 inches, yellow glandular; pistillate 2- to 10-flowered. March to May.

Fruits often clustered, flattened, 1 to 1.50 inches long, about 1 inch wide. Nut flattened, reddish brown. Seed very bitter. September to November.





ater Hickory/*Carya aquatica*
ichx. f.) Nutt.

W. Gupton
ginia Military Institute
xington, Virginia

ter hickory is primarily a subclimax tree of the Coastal Plain forests.
found most often in poorly drained heavy clay flats and sporadically
wamp forests. The largest specimens of water hickory are found in
lower Mississippi Valley. Although it requires abundant moisture
light for good early growth, water hickory can withstand consider-
e shade and competition after establishment. Stump and root sprout-
is prolific on trees up to 24 inches in diameter.

Although squirrels eat the seeds of water hickory, it is one of the
kories least preferred by wildlife. In areas with good squirrel popula-
ns nuts are cut but few seeds are eaten. Nuts have been found in the
machs of mallard and wood ducks.

Optimum seed-bearing age ranges from 40 to 75 years. An
imated 20 to 30 pounds of fruit were observed under a large tree
ate January. Late freezes seriously affect flowering and fruiting

Transplanting, budding, and grafting are difficult. Propagation is
seed. Planting is best done in early spring to reduce rodent destruc-
n; however, the bitter taste of the seeds minimizes this problem. Seeds
uld be stratified in sand or peat at 30 to 35°F for 90 to 150 days.
eds dry-stored for a year need only 30 to 60 days of stratification.
nts are susceptible to leaf mildew and witches' broom [*Micro stroma*
landis (Berenz.) Sacc.] and to common white wood rot (*Fomes*
iarius Fries).

The wood is soft, brittle, close-grained and dark brown, and is used
le except for fences and fuel.

Fire causes both bud and stem rots. Pigs eat many of the seeds
d seedlings.

Other common names: bitter pecan, swamp hickory, wild pecan.

Bitternut Hickory/*Carya cordiformis* (Wangenh.) K. Koch

O. W. Gupton
Virginia Military Institute
Lexington, Virginia

Bitternut occurs in moist or dry woods, in mountain valleys, along stream banks, and in swamps. It is probably the most rapid growing c all the hickories and holds its foliage longer than the other species. Well drained, sandy or clayey loams are most suitable. Bitternut is th most abundant and uniformly distributed of the hickories. Although i is usually found on wet bottomlands it is hardy on much poorer soils Its life span is about 200 years.

Seeds of bitternut do not usually constitute a large portion of the diet of squirrels. In an area of good squirrel population in Virgini large quantities of fruits, mostly uncut or with seeds partially eaten, were found on the ground in late February. Optimum seed-bearing a ranges from 50 to 125 years.

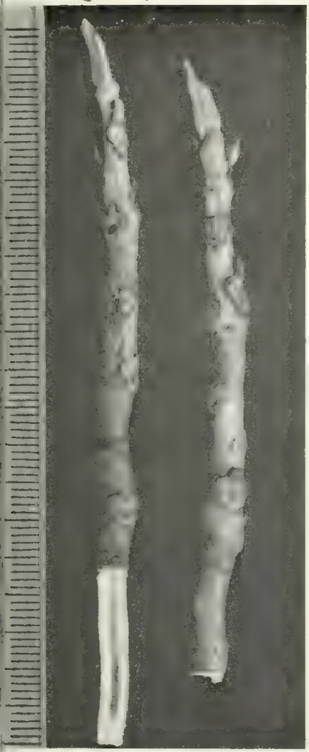
Propagation is by seed and is usually best in early spring. The stock is much used in grafting and budding. This species sprouts fro stumps more vigorously than other hickories.

The wood is hard and used for tool handles, hoops, boxes and crates, furniture, flooring, and fuel (especially in smoking meats). Bu ing occurs with an intense flame and little ash is deposited.

Diseases are leaf mildew and witches' broom [*Microstroma juglandis* (Berenz.) Sacc.] and common white wood rot (*Fomes igniarius* Fries).

This a good park or shade tree.

Other common names: swamp hickory and pignut.



Bitternut Hickory

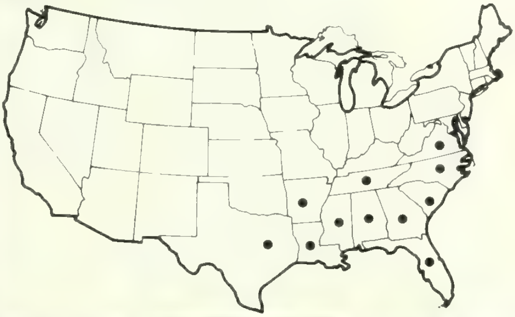
A tree 50 to 80 feet and up to 170 feet, with stout limbs and a broad spreading head.

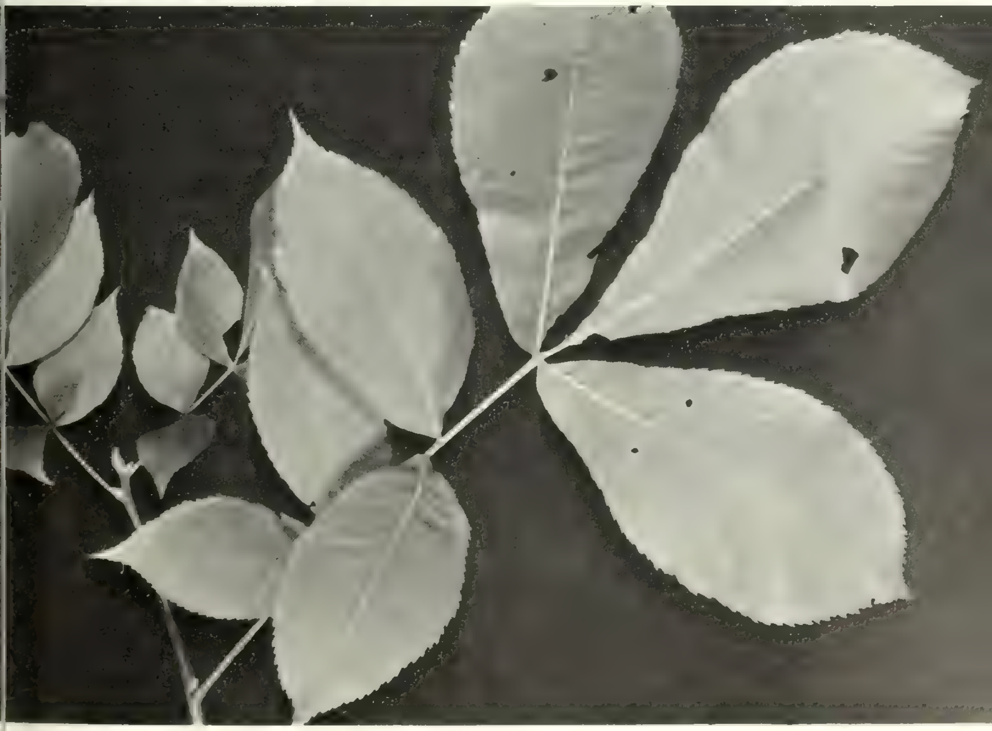
Leaves 6 to 12 inches long, 7 to 11 leaflets on a glabrous rachis.

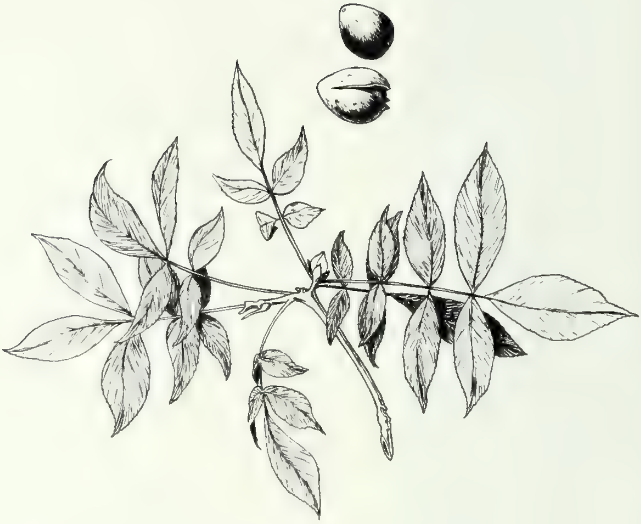
Twigs greenish brown to reddish brown; winter buds scurfy, bright yellow.

Flowers in catkins, staminate in threes, 3 to 4 inches long, reddish hairy, pistillate in one's and two's, sessile. April to May.

Fruits slightly flattened; husk yellow, scaled. Nut globose to ovate, abruptly pointed into a conical beak. Seed bitter. September to October.







Pignut Hickory

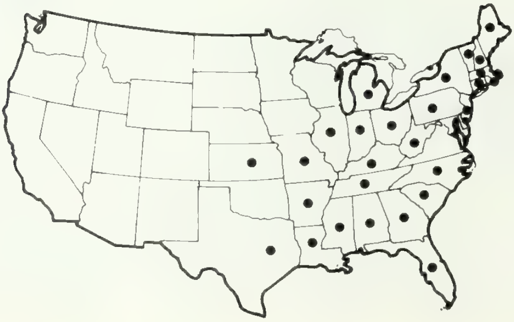
A tree usually 80 to 90 feet tall, but may reach 120 feet.

Leaves yellowish green and glabrous above, paler below, 8 to 12 inches long, three to seven leaflets, sessile and ovate.

Twigs reddish brown, glabrous, dotted with pale lenticels, long terminal buds, glabrous pale brown.

Male flowers yellowish green, catkins 2 to 2.50 inches, three branched; pistillate, few flowered. April to May.

Fruit brownish, pear-shaped, about 1.25 inches long and 0.75 inch wide, hull tardily dehiscent, nut thick shelled, meat usually sweet but astringent, sometimes bitter. September and October.



Pignut Hickory/*Carya glabra* Mill.) Sweet

owell K. Halls
orest Service, USDA
acogdoches, Texas

ignut is the hickory most commonly found in the Appalachian forest, nd is considered a climax species throughout its range. It generally habits dry ridges and hillsides with well-drained upland soils but is lso common on moist sites in the southern Appalachians. It is assoc- ted with many species of oaks and in the Piedmont, with pines. The ecies is intolerant of shade in the Northeast and tolerant in the South.

Optimum fruit production occurs at 75 to 200 years of age.

The species has been cultivated for many years and responds well increased fertility. It sprouts prolifically from stumps, but is difficult reproduce from cuttings. It is slow-growing and hard to transplant.

Pignut hickory is easily damaged by frost and fire. It is also damaged r injured by sapsuckers, anthracnose, bark canker, trunk rot, and by eetles. It is probably one of the most preferred foods of a twig girdler nd is attacked by several species of gall insects.

The wood is used for fuel, tool handles, wagons, and agricultural nplements.

Other common names: oval pignut hickory, red hickory, broom ickory, redheart hickory, small-fruited hickory, sweet pignut, and witch hickory.

Shagbark Hickory/*Carya ovata* (Mill.) K. Koch

Kenneth A. Nicely
Virginia Polytechnic Institute and State University
Blacksburg, Virginia

Shagbark hickory occurs throughout the eastern hardwood deciduou forests on many kinds of sites and with many other species. In botton lands, it may be associated with *Quercus alba, C. laciniosa*, and *Plata occidentalis;* in better drained areas it may be associated with *Acer rubrum, Fagus grandifolia*, and *Q. rubra*. In the North it occurs abunda on upland areas and reaches its greatest size and best development the western slopes of the Allegheny mountains and the lower Ohio Valley.

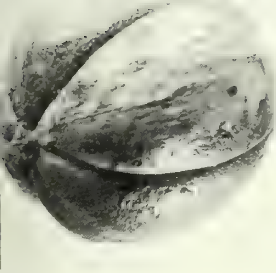
The species is moderately tolerant to shade and is able to perpetuate itself in the eastern hardwood forests. Although slow-growin it is probably one of the fastest-growing hickories. It reproduces readi by sprouts, a factor which is of importance in reproducing the specie after fires. It develops a strong, deep taproot and is rarely damaged wind. The tree is attacked by several leaf parasites, and the fruits are especially subject to attack by the hickory weevil (*Curculio caryas*), a insect that also does extensive damage to the pecan.

Average yield of nuts is 2 to 3 bushels per open-grown tree with extreme yields up to 18 bushels.

The nuts of the shagbark are eaten by squirrels from the time th fruits approach maturity in August, to their prime in September and October, and to the next spring wherever they are found on the fore floor or in logs and stumps. The thickness and hardness of the shell is probably a major factor limiting the use of this fruit by some game animals. The nut is very tasty to humans and is the common hickory nut of commerce.

Other common names: Carolina hickory, scalybark hickory, she bark hickory, white hickory, sweet-walnut, upland hickory.

Shagbark Hickory



A tree 70 to 90 feet in height, rarely reaching 120 feet.

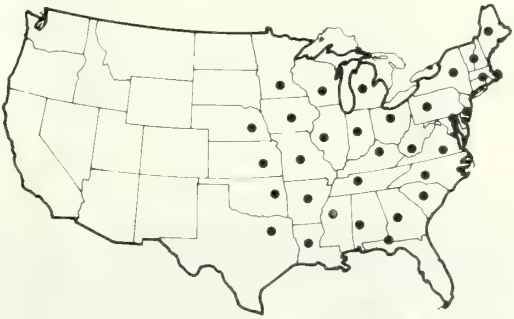
Leaves 10 to 14 inches long; five to seven leaflets, upper surface glabrous, lower surface glabrous or pubescent; individual leaflets serrate and ciliate, the hairs denser and forming a ‘tuft’ near the apex of each serration.

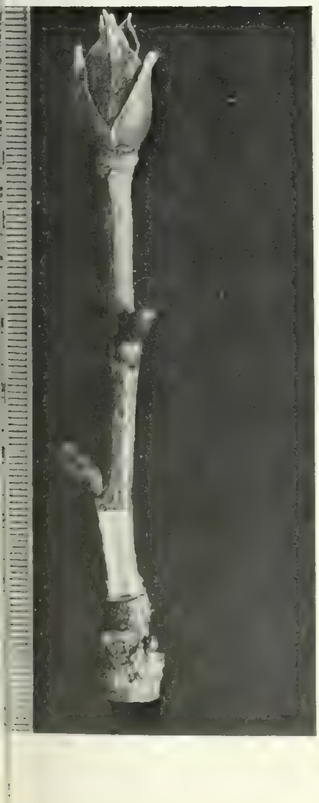
Twigs stout, usually pubescent; terminal bud 0.50 to 0.75 inch long, three to four dark brown outer loose-fitting scales.

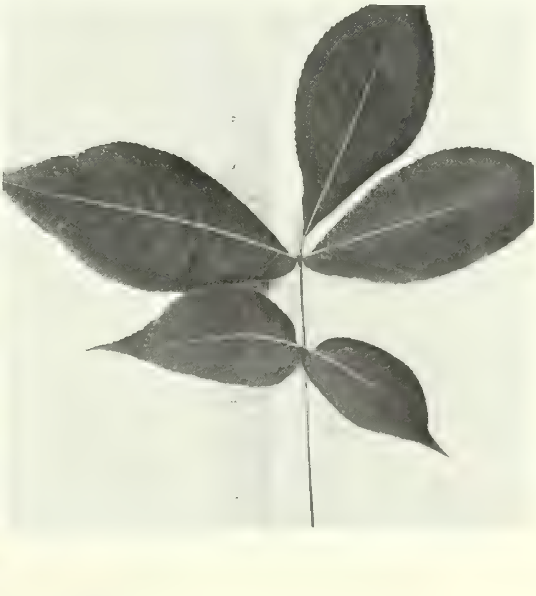
Male flowers in slender light-green catkins up to 4 inches long; pistillate, borne in two- to three-flowered spikes.

Bark light gray, 0.75 to 1 inch thick, tight when young but later separating into strips up to 1 foot or more in length which remain attached, giving the characteristic shaggy appearance.

Fruit 1 to 1.50 inches in diameter; nut prominently or obscurely four ridged. September and October.







Mockernut Hickory

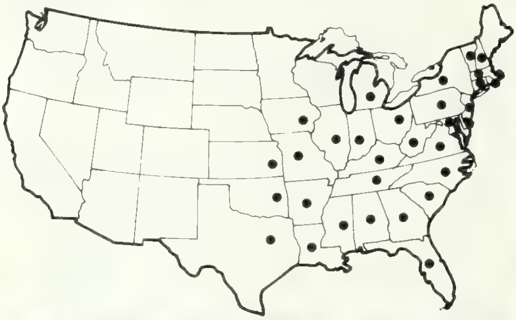
A tree up to 100 feet tall, 3 to 5 feet in diameter at breast height.

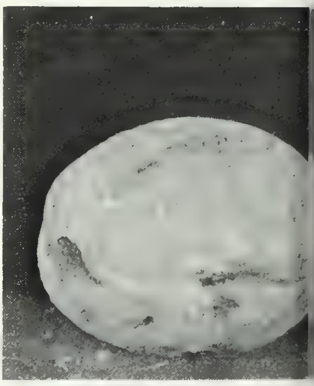
Leaves 8 to 24 inches long with five to nine leaflets, lateral leaflets sessile, 5 to 8 inches long, 2 to 5 inches wide, shiny yellowish green above, paler below, brownish-orange hairs.

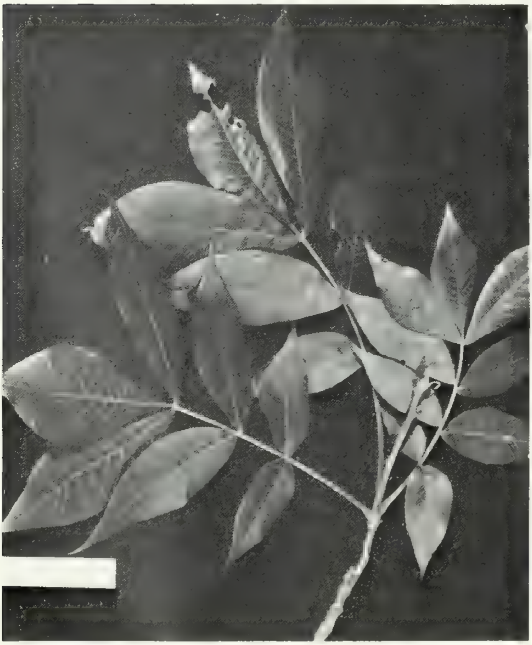
Twigs stout, grayish brown to reddish, buds large 0.50 to 1 inch, yellow and tomentose.

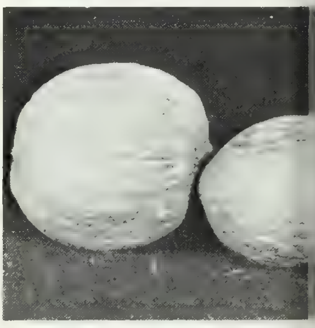
Male flowers three branched, 4 to 5 inches long, yellowish green, hairy; pistillate two to five flowered, dark red.

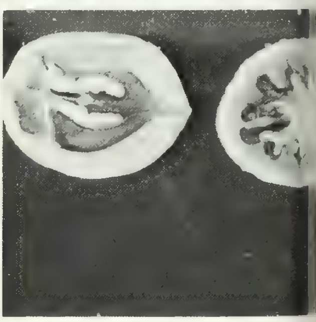
Fruits solitary or paired, globose, 1 to 3.50 inches long, short necklike base. Hull dark reddish brown, hairy with yellow resinous dots, four ribbed; nut brownish white, shell thick, kernel sweet. September and October.











Mockernut Hickory/*Carya tomentosa* Nutt.

owell K. Halls
orest Service, USDA
Nacogdoches, Texas

Mockernut hickory is usually found as a component of the eastern ak-hickory forest. It also occurs in beech-maple forests and is the only ickory found in the pine forests of the sandy belt of the southern states. Most of the merchantable mockernut grows on moderately fertile upands, attaining its best development only on deep fertile soils. The pecies is intolerant, but it recovers rapidly from suppression.

Mockernut is a preferred mast food for squirrels. Nuts are cut while ill green. Gray squirrels cut hickory nuts into small pieces, but flying quirrels cut a hole in one end, from which the edible kernel is extracted. he nuts are also tasty to humans but the trees are seldom cultivated or fruit.

Best production of fruit is at 40 to 125 years of age.

Mockernut is extremely susceptible to fire. It is often damaged eriously by the hickory bark beetle.

The wood is used for vehicle parts, handles, fuel, and agricultural mplements.

Other common names: bullnut, white hickory, white heart hickory, ognut,.whitebark hickory, fragrant hickory.

***Chinkapin/ Castanea* spp.**

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

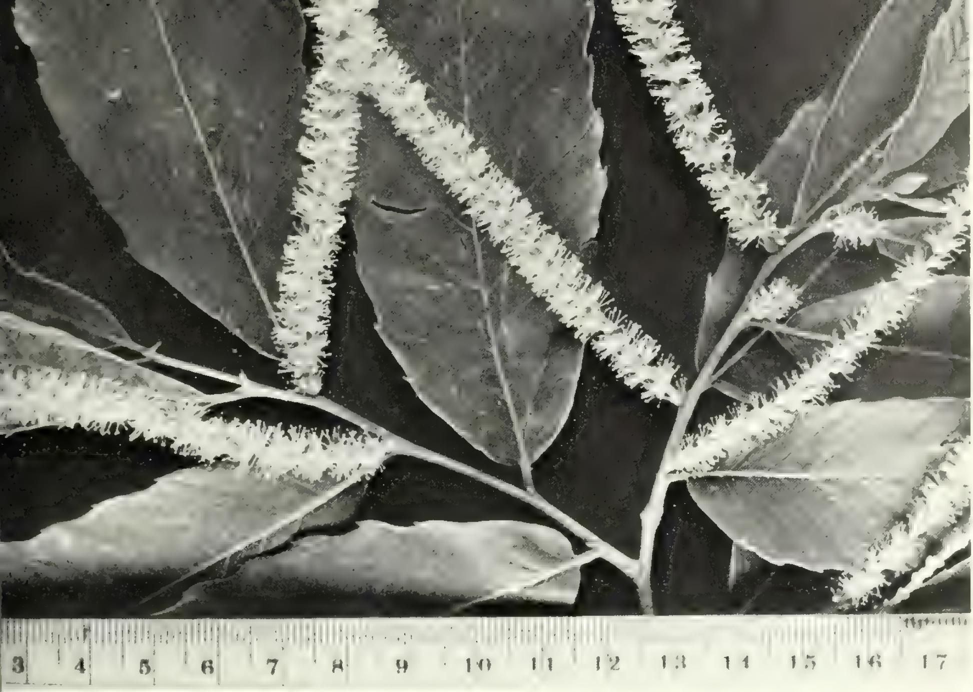
Two species of chinkapin are commonly found throughout the South.

Castanea pumila (L.) Mill. is a large shrub or tree with branchlets more or less pubescent and leaves densely tomentose beneath. It grow in sandy open woodlands and thickets. It has two variants: Allegheny chinkapin (*C. p.* var. *pumila*) and Ashe chinkapin (*C. p.* var. *ashei* Sud Allegheny chinkapin is a thicket-forming shrub or tree. The bur is close covered by scales bearing short erect crowded slender bristles. Ashe chinkapin is a shrub or small tree with usually several trunks from the base. The bur has broad open areas and somewhat remote scales that bear horizontally divergent short bristles.

Castanea alnifolia Nutt. is a small shrub or arborescent shrub. Th branchlets typically are smooth and leaves thinly tomentose beneath. The species grows on rolling hills on open woodlands and in thickets. It also has two variants: Downy chinkapin (*C. a.* var. *alnifolia*) and Florida chinkapin (*C. a.* var. *floridana* Sarg.). Downy chinkapin is a da erect colonial shrub that spreads by underground rootstocks. Florida chinkapin is an arborescent, noncolonial shrub.

The nuts of both species are eaten by a number of birds and by small mammals such as squirrels, rabbits, and chipmunks. The kernels are sweet and edible to man.

The tree-forms have occasionally been used for posts, crossties, and fuel, but the plants seldom grow large enough for commercial use



Allegheny Chinkapin

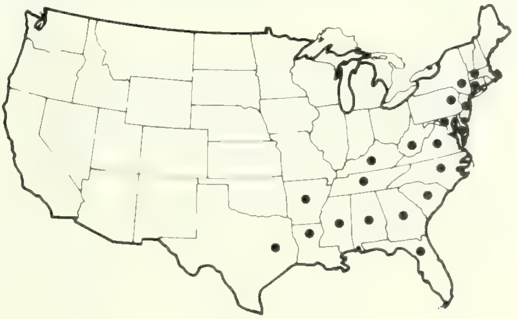
A tree or shrub up to 50 feet high, often with many trunks from the base.

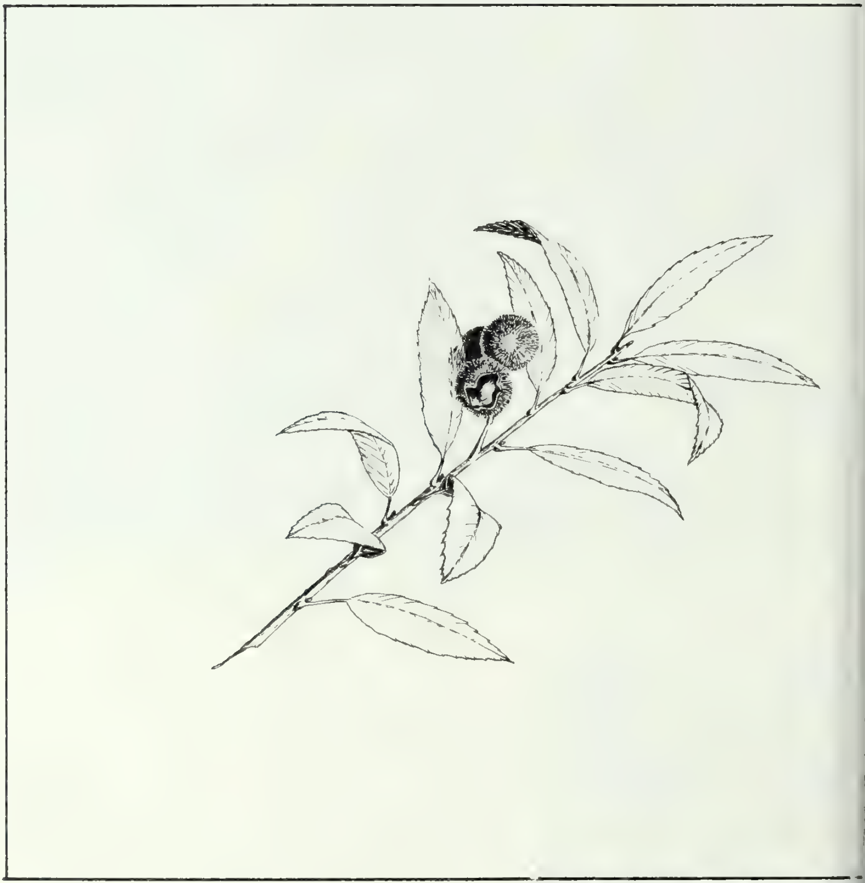
Leaves alternate, simple, deciduous, elliptic, bristle-toothed margin, green and glabrous above, whitish-downy to white-glabrate below, 3 to 4 inches long, 1 to 1.50 inches wide, petiole stout and glabrous.

Twigs reddish brown, slender, pubescent or glabrous. Bark furrowed.

Flowers borne in two kinds of catkins on same tree, one bearing all male flowers, another with male and female. Staminate catkins 4 to 5 inches long, cylindric.

Fruit a bur, spines stout, pubescent. Bur splits into two to four valves bearing one to three shiny brown nuts, 0.50 to 0.75 inch long. Late summer and early fall.



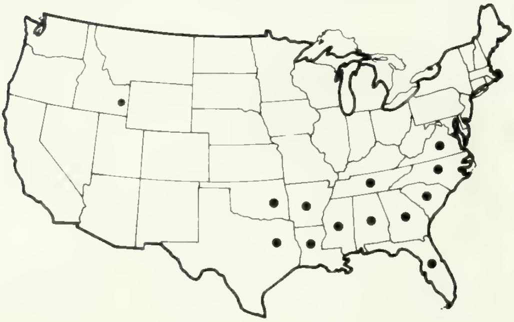


Downy Chinkapin

A shrub with underground rootstocks and erect branches.

Leaf-blades cuneate to lanceolate with a cuneate base, 2 to 4 inches long, obtuse or opiculate at the base, with tawny or dirty-white tomentum beneath.

Fruit is a solitary nut 0.60 to 0.80 inches long.



American Beech/*Fagus grandifolia* Ehrh.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Beech grows on fertile bottomlands and uplands, preferably in cool, shady, moist locations. It is seldom found in limestone valleys. Beech is very tolerant and throughout most of its range is considered a climax species. It is highly susceptible to frost. It is associated with a large number of other hardwood species, mainly maple, birch, magnolia, basswood, black cherry, oaks, and hickories.

Beech trees develop well under partial cuttings or singletree selection cuttings, but they do poorly when forest stands are heavily cut or clearcut. Trees that have been injured or suddenly exposed by cuttings often develop epicormic branches.

Beechnuts are eaten by many kinds of birds and mammals. They are a favorite food for squirrels, which also eat the catkins. The nuts and buds are choice for wild turkeys. The nuts are a preferred food of ruffed grouse, chipmunks, and black bear and are occasionally eaten by bobwhite quail. The small sweet edible nuts are sometimes gathered and sold commercially and are a source of vegetable oil and hog food. The first nuts to fall are usually wormy or aborted.

Seeds are high in crude fat and calcium and moderate in crude protein and phosphorus. Optimum production of fruit is when trees are about 60 years of age. Trees tend to have either very good or very poor crops.

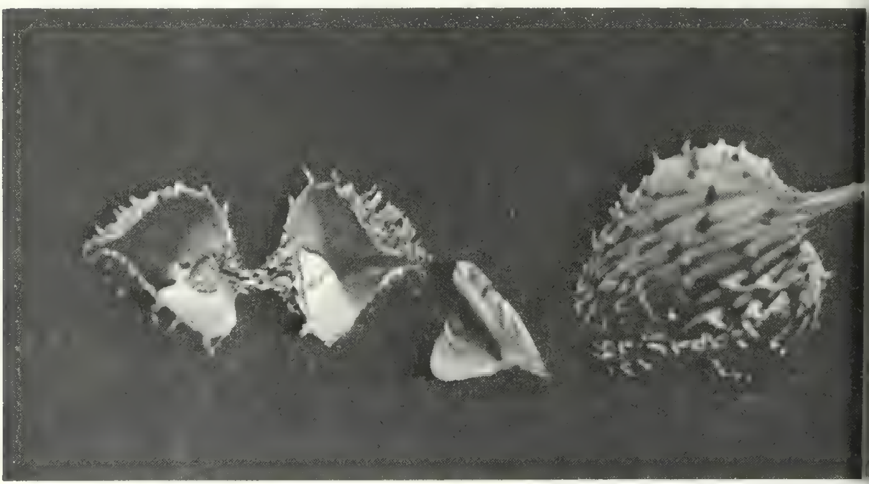
The seed can be sown immediately in the fall or stratified in sand at 41°F for 60 to 90 days for spring sowing. Rodent protection is necessary and partial shade required for most of the first year. Transplanting s usually done with 1- to 3-year-old plants. Seedlings develop better under shade than in openings, and many seedlings are found beneath dense stands.

The most serious insect pest of beech is the scale which serves as a predisposing agent for infection by the *Nectria* fungus. Because of its hin bark, beech is susceptible to fire and susceptible to sunscald in tands that have been opened.

The tree is very desirable for ornamental planting, but it is difficult o grow grass beneath the heavy foliage.

The wood is commercially sold for fuel, and for wood products such as tool handles, flooring, cooperage, and toys.

Other common names: beech, red beech, ridge beech, white beec and beechnut.



American Beech

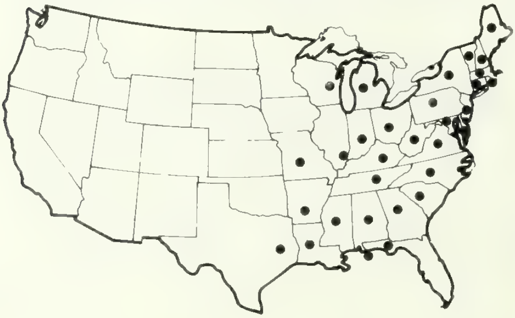
A tree averaging 60 to 80 feet in height, but may become 170 feet tall.

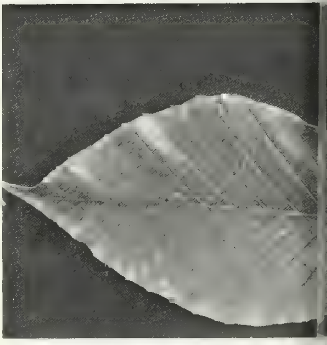
Leaves pale yellowish-green, oblong, coarsely serrate, veins beneath silky, deciduous, alternate, 3 to 6 inches long.

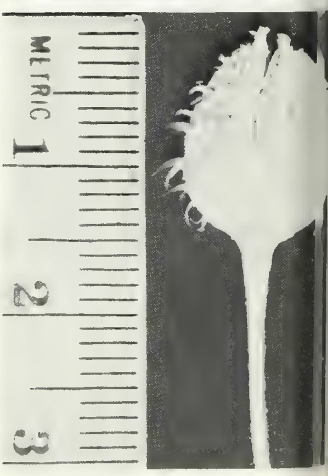
Twigs reddish brown to light gray with age, light-tan lenticels on new growth, hard pith, alternate leaf and bud scars, buds up to 1 inch, six times longer than wide, scales reddish tan, terminal buds present.

Flowers borne in lateral clusters in early spring monoecious.

Fruit a pair of small, brown, three-angled sweet nuts in burlike involucre. September to November, persistent seeds fall after first heavy frost.







***Butternut*/*Juglans cinerea* L.**

Donald D. Strode
Forest Service, USDA
Washington, D. C.

The butternut prefers rich, moist, well drained loams; however, it is found on drier rocky sites, especially sites with a limestone origin. It is very intolerant of shade and never occurs in pure stands but is found singularly or in small groups in association with other hardwoods. It is not an important timber species.

Because of its extensive range, butternut is associated with many species. Common associates include basswood, black cherry, beech, black walnut, elm, hemlock, hickory, oak, red maple, sugar maple, yellow-poplar, white ash, and yellow birch. Butternut is used occasionally for boat building and interior decorating. It is also used by wood carvers. The wood can resemble black walnut when properly finished. The kernel of the nut is sweet, oily, and edible. The species is called "butternut" because of the oily kernel which may become rancid like butter.

As does black walnut, butternut has an "antagonistic" action that causes withering and death in certain cultivated plants. The toxic material is localized in the vicinity of the roots.

Various species of animals eat butternuts, including white-tailed deer, cottontails, and squirrels. But because of its scattered occurrence, the over-all value of butternut for wildlife is small. The seeds are buried by rodents, chiefly squirrels, and this accounts for a large share of the seedlings in natural stands.

Optimum seed-producing age is 30 to 60 years. A tree can produce from one-fourth to one bushel of seed.

The most serious and widespread disease of the species is an ascomycete, *Melanconis juglandis*. The disease is slowly progressive and eventually kills the tree. Butternut is very susceptible to fire damage. Although this species is generally wind-firm it is subject to frequent storm damage.

Early settlers used the inner bark of butternut for medicinal purposes. Pioneers extracted a dye from the husks for coloring homespun clothing. During the Civil War, backwoods troops were called "Butternuts" after the color of their clothes.

Other common name: white walnut, oilnut

Butternut

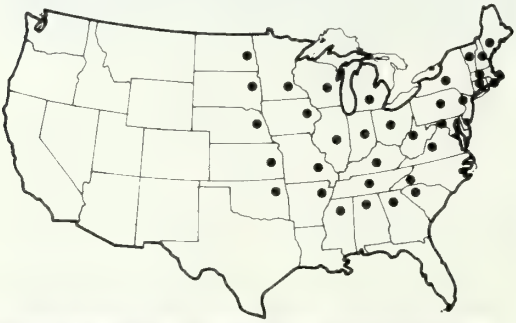
A small- to medium-sized tree up to 70 feet tall with diameter of 3 feet; trunk usually short and divided into several large spreading branches.

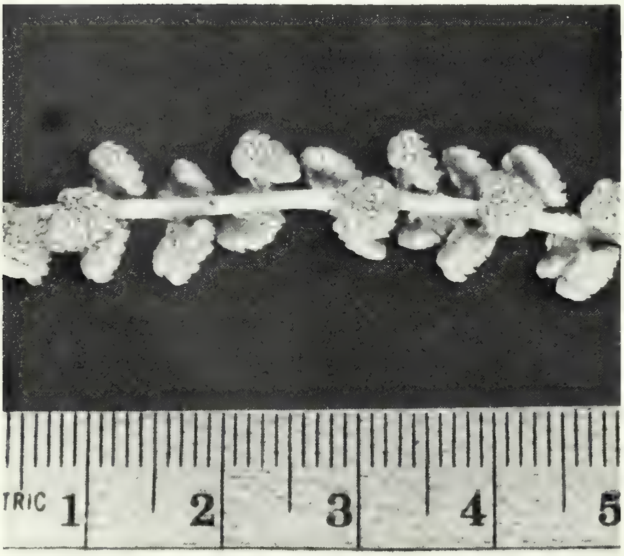
Leaves alternate, deciduous, 10 to 25 inches long, odd pinnately compound, 11 to 19 leaflets, elliptic, 2 to 5 inches long, 1.50 to 2 inches wide, yellowish-green and fine pubescent above, paler below.

Twigs reddish brown to gray, puberulent, lenticels pale and abundant, leaf scars large, bundle scars in three V-shaped groups, terminal bud 0.50 to 0.75 inch long, scales entire, pith thin-plated, diaphram thickened.

Flowers monoecious, male catkins 1.50 to 5 inches long, greenish; female solitary or several together, five- to eight-flowered. April to June.

Fruit a nut deeply sculptured and rough with ragged ridges, covered with a fibrous fleshy husk. September and October.





Black Walnut/*Juglans nigra* L.

Donald D. Strode
Forest Service, USDA
Washington, D. C.

Black walnut is one of the best known and most valuable hardwood species. It is very sensititve to soil conditions and requires a deep, well-drained, nearly neutral soil with a generous supply of moisture and nutrient material for best growth. It is generally found as scattered trees throughout forested areas. Primary associates include yellow-poplar, white ash, black cherry, basswood, beech, sugar maple, oaks, and hickories. Black walnut is rated from intolerant to very intolerant of shade.

Although all native walnuts are useful to wildlife, the black walnut is the most important. The large, distinctively flavored nuts furnish food for red squirrels in fall, eastern gray squirrels in fall and winter, and are important in the diet of eastern fox squirrels. All nuts buried by squirrels are not recovered; therefore, these animals are important in establishing new trees. Best fruit production begins when trees are about 30 years old and continues for another 100 years. Large trees can produce several bushels of nuts in one year.

The kernel portion of the fruit is very high in crude protein and crude fat and high in phosphorus.

The wood of black walnut is noted for its beauty and the ease with which it is manufactured into fine furniture and cabinets. It is highly prized for hand carving and is preferred for gunstocks. The wood is durable and is used for railroad ties and posts.

The nuts of black walnut have a distinctive flavor and many rural families collect and sell nuts to commercial extractors who use the meat for cookies, candies, and other confections.

Walnut trees damage other plants severly when roots come into direct contact.

Normal freezing and thawing usually will cause seeds to break dormancy the spring after maturation, but germination is often delayed until the second year.

The species has few important insect enemies. The most serious is the walnut caterpillar (*Datana integerrima*). Trees are seldom killed;

however, some loss in current growth by defoliation usually occurs. Black walnut is wind-firm and not easily damaged by ice and windstorm The thick bark and naturally durable heartwood make it resistant to damage and decay after fires.

Black Walnut

A tree up to 125 feet tall and 4 to 5 feet in diameter at breast height.

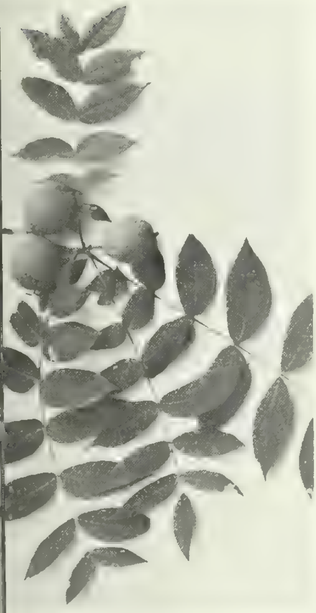
Leaves compound, 1 to 2 feet long, with 15 to 23 dull-green serrately margined leaflets. Leaflets opposite and approximately 1 inch wide and 3 inches or more in length, fragrant when crushed.

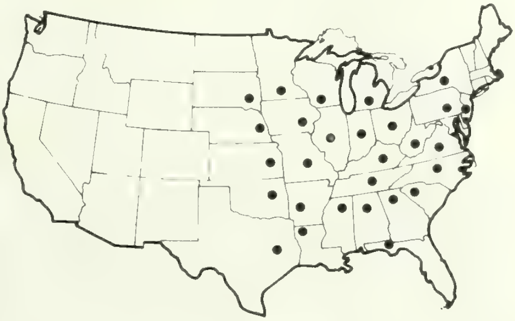
Twigs stout, more or less hairy, orange-brown to light brown with buff-colored, finely chambered pith. Leaf scars large, V-shaped and conspicuous.

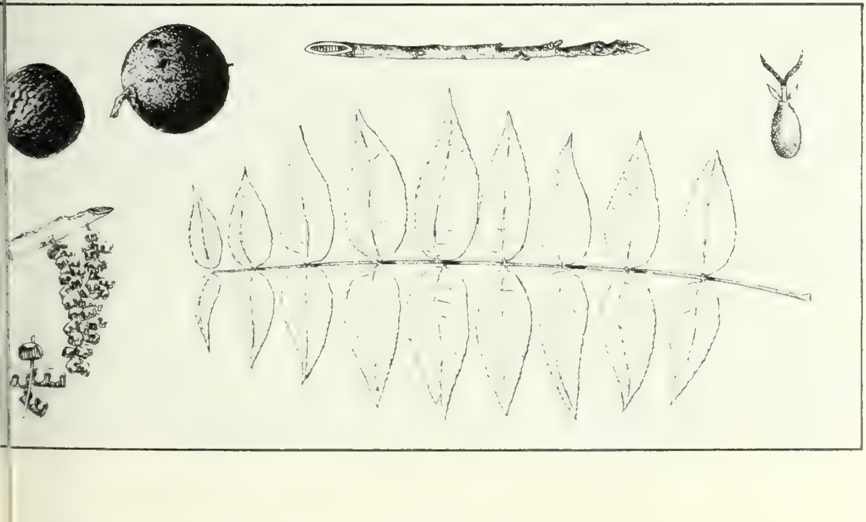
Flowers monoecious, male catkins 2 to 5 inches long, female flowers in 2- to 5-flowered spikes, about 0.25 inch long.

Fruit an ovoid, corrugated, sweet, edible nut 1.12 to 1.50 inches long, enclosed in a thick, hairy, yellowish-green husk, borne solitary or in clusters of two or three. September to November, fall at maturity.

Bark light brown and scaly on young stems, becoming dark brown and deeply fissured into broad, rounded, intersecting ridges on old trunks.







Eastern Hophornbeam/*Ostrya virginiana* (Mill.) K. Koch

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

This small understory tree grows best in rich moist woods in association with other hardwoods; however, it grows in a wide variety of soil and moisture conditions. It is a slow grower and not aggressive.

The fruits, buds, and catkins of hophornbeam are eaten by severa kinds of birds and mammals. Hophornbeam ranks high as food for ruffed grouse, and is used by bobwhite quail, squirrel, deer, cottontail, ring-necked pheasant, purple finch, rose-breasted grosbeak, and dowr woodpecker. Seeds are a preferred winter food of wild turkey. Hophor beam also provides some nesting and escape cover for birds and mammals.

The seeds are high in crude protein, crude fat, crude fiber, phosphorus, and calcium.

The preferred method of establishing hophornbeam is to plant 2-foot high or taller stock in masses or groups in forest openings, woo land borders, or old fields. If planted by seed the species should be so in fall or stratified over winter in sand or peat at 41°F and sown in spring. Natural regeneration is mainly by seed, which germinate in the first spring after seed fall.

The hops dry and gradually fall apart soon after ripening and are dispersed largely by wind, but occasionally by birds. Seed production p plant varies from year to year. The plants do not produce seed in quan until about 25 years old.

Other common names: American hophornbeam, hornbeam, hc hornbeam, ironwood, deerwood, leverwood, hardhock.

Eastern Hophornbeam

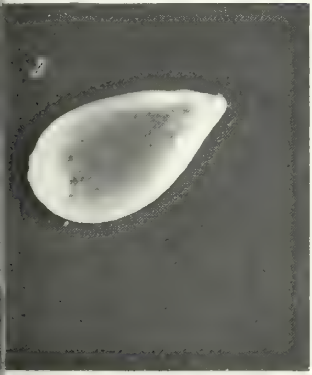
A small, slow-growing tree up to 60 feet tall.

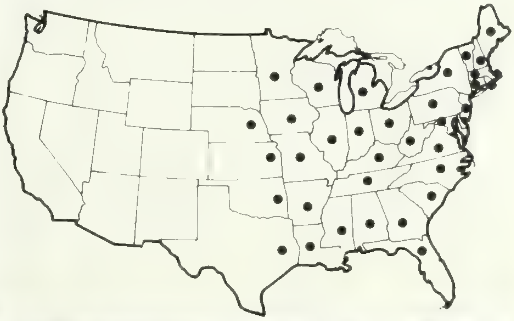
Leaves simple, deciduous, 2.50 to 4.50 inches long, 1.50 to 2.50 inches wide, margin sharply and doubly serrate, glabrous and yellowish green above, hairy and paler below.

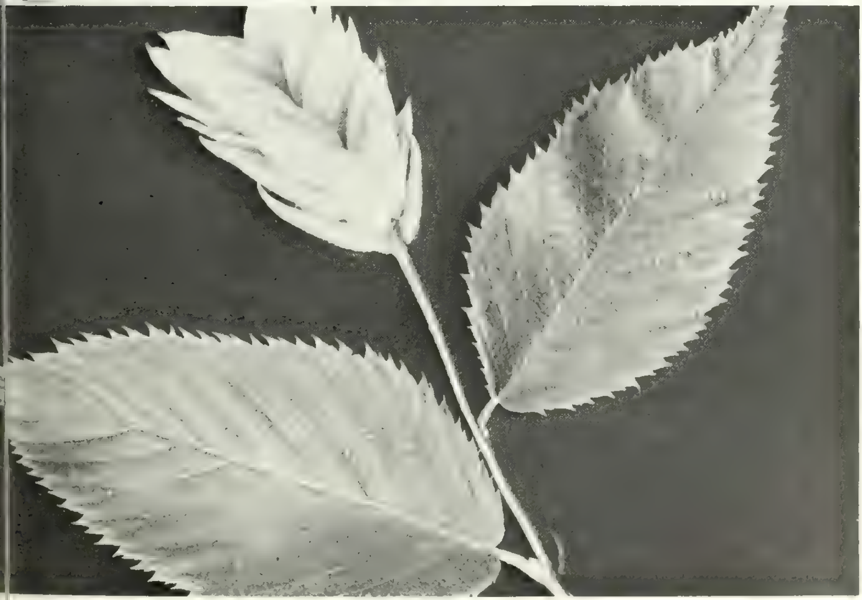
Twigs reddish brown to brown with white lenticels, bud scales with fine longitudinal striations, yellowish green with purple-brown edges, leaf scars half round to crescent shaped with three bundle scars; crooked, slender, pubescent.

Flowers monoecious, male catkins, 1 to 3 inches long, one to three at end of branches; female catkins small, solitary, slender. March to May, with leaves.

Fruit a flattened ovoid nutlet, in conelike imbricate clusters, nuts 0.25 inch in diameter enclosed in the sac, cluster 1.50 to 2 inches long. September and October.







Oaks/*Quercus* spp.

owell K. Halls
orest Service, USDA
acogdoches, Texas

Oaks are the most important and widespread hardwood trees in temperate regions. They include some of our largest and most stately trees,' ut some are shrub-like. They thrive at different altitudes and in many oil types.

Some species are deciduous, others evergreen. The leaves are ternate and simple. Winter buds, clustered at the ends of twigs, are omposed of many overlapping scales. Minute flowers are borne in early pring with the leaves. Male and female flowers are on the same tree. ale flowers are in clustered, drooping, slender, yellowish catkins. emale flowers are solitary or few and greenish. The fruit is an acorn hich matures in one or two years and sheds soon afterwards in autumn. has a hard shell, a cup of overlapping scales, and a seed.

Oaks are classed into two groups. The red or black oaks have leaves ith apexes and bristle-tipped lobes; their acorns usually mature the econd year. White oaks have leaves with apex and lobes that are not istle-tipped; their acorns mature the first year. With a few exceptions, eeds of the white oak group have little or no dormancy, and will germinate soon after falling. Acorns of the black oak group are usually ormant and germinate the following spring under natural conditions. or germination to occur the moisture content of acorns must not drop elow 30 to 50 percent for white oaks and 20 to 30 percent for red oaks.

Most oaks are intermediate in tolerance, and young plants can ompete in a broad range of light tolerance if soil moisture is adequate. here is high mortality among newly established oak seedlings; few rvive the first year without dying back and sprouting at least once.

Upland oaks can be established by seeding or planting. Recently rested sites are generally better than abandoned fields. Lack of repelnts to protect acorns from animals severely limits direct seeding, but aks can be planted readily by conventional methods and will survive ell on suitable sites. They require ample sunlight for best growth, and ompeting vegetation must be controlled.

In managing oaks for wildlife at least half of the oak trees in the and should be at least 40 years of age. If clearcutting is the regenera-

tion method the cutting units should be small and well distributed o
the management unit. No more than one-eighth of the unit should b
regenerated during any cutting cycle.

A small residual basal area distributed in a few large trees can produce a bumper crop of acorns.

Acorn crops vary from nearly zero to 250,000 or more acorns p
acre. Many times the white oak group will produce in a particular ye
and the red oak group will have practically no yield; at other times, t
opposite occurs.

The number of acorns depends on the size of the tree crown, which is closely related to stem diameter at breast height, to site, an
also to the inherent ability of the individual tree to bear fruit. Some trees never bear many acorns whereas others are always heavy produ
in good mast years. Average annual yields of fresh acorns for some
the larger trees may be 18 pounds or more, but may be considerabl
less in other years. In West Virginia, red oaks produced a yearly aver
of 170 acorns per milacre of crown cover as compared to 96 for the
white oaks. Size of acorn crop showed no relation to site quality. Immature acorns made 34.7 percent of the total crop. The condition o
all acorns was: sound 13.5 percent, insect damage 32.8 percent, ani
damage 52.2 percent, and other 0.5 percent. The amount of sound,
undamaged acorns varied from 11 percent to 73 percent between years.

Many acorns are lost to nut weevils and gall insects, and by destructive forces such as freezing, drying out, burning in wildfires, and flooding. These forces account for relatively large losses in poor cro
years and relatively small losses in good crop years. Only about 46 percent of the acorn crop falls to the ground in sound condition. In
southern Appalachians the greatest damage to well-developed acorn
was caused by insects, ranging from 26 to 81 percent.

Oaks exceed all other tree groups in their contribution to wildlif
food. Innumerable kinds of birds and mammals avidly eat the acorn
the only source of high energy through winter months in many area
Animals fatten quickly, go through the winter in good condition, an
most likely to breed and grow healthy young when acorns are availa
In fact, the breeding success of game animals such as squirrels and white-tailed deer is closely linked to acorn yields in hardwood forest
During years when the acorn crop fails many animals go hungry an
hard-pressed for survival.

Acorns from the white oak group are considered the most palat
Black oak acorns tend to be bitter, have a higher tannin content, an

used less than the white oak group when both are available. The relative low palatability of the black oak acorns may be an advantage in hat many of them are buried and stored and eaten in late winter or early spring when food shortages are often acute.

Acorns are particularly important to several kinds and groups of mammals and birds. Acorns in shallow ponds and streams are a great enticement to mallard and wood ducks, causing them to remain over winter when an ample supply is available. Squirrels eat the oak catkins n spring and eagerly search for acorns wherever they are available. Bobwhite quail eat the smaller acorns whole, and they pick up fragments or pick out the meat of larger ones. In some areas acorns are the most mportant staple food for wild turkeys, particularly in the winter. In Louisiana, turkeys almost always locate their winter range where acorns are available. Turkeys eat the acorns whole regardless of size. In wild urkey management it is suggested that oaks constitute at least 30 percent of the mast-producing potential and that one-third of the oaks be n the white oak group. Ruffed grouse eat acorns throughout the year. Woodpeckers, black bears, and raccoons have a special appetite for acorns. In Florida, acorns and other nuts comprised nearly one-half of he bluejay's total food. White-tailed deer are fond of the large acorns and they also browse on the foliage and twigs of some oak species.

Oaks also provide useful wildlife cover. They furnish nests and den rees for birds and for small climbing mammals. Oak leaves and twigs are used by many birds for nesting materials.

Acorns are high-energy foods and animals fatten readily on them. Some oak species are high in crude fat content (mainly the red and black oaks); nearly all species are low in crude protein, phosphorus, and calcium. Acorns in the black oak group generally have a higher fat content than those in the white oak group.

Wood from oaks is used widely for furniture, building materials, ooperage, and fuel. Trees are used as ornamentals in yards, parks, nd along city streets.

White Oak/*Quercus alba* L.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

White oak grows on a wide range of soils and sites within its range except the extremely dry, shallow soil ridges, poorly drained flats, and wet bottomlands. It does best on deep, well-drained loamy soils on northerly and easterly lower slopes and coves, and is moderately susceptible to frost. It is closely associated with other oaks, hickories, and large variety of hardwoods and pines. It seems to have been replaced by Durand oak in northeast Florida.

White oak tends to have either very good or very poor fruit crops Acorn yields per tree are extremely variable. The average is probably 700 to 1,000 acorns per tree, but yields up to 7,700 acorns per tree have been reported. Some trees are consistently better producers tha others. Seeds germinate almost immediately after falling. When the moisture content of the embryo falls below 50 percent of the dry weig viability is greatly reduced.

Much of the second-growth white oak has originated from sprou following cutting or fire. Seedlings persist for many years beneath a forest canopy even though the tops may die back. Opening of the for stand by cutting results in the rapid growth of the seedling sprouts pre ent . White oak is considered a slow-growing tree, but when not overtopped it grows faster than hickories and nearly as fast as red and black oaks.

White oak is generally considered intermediate in shade toleran It tends to become dominant in a stand, and usually prunes well in moderate to heavily stocked stands. When associated with other oak and hickory, in the central and southern hardwood forests, it is consi ered a climax tree.

Decay of heartwood resulting from fire scars causes the most ser losses in white oaks. It is rather free of insect pests.

Other common names: fork-leaf white oak, ridge white oak, sta oak.

White Oak

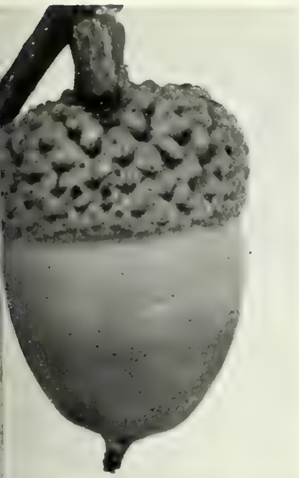
A tree 80 to 100 feet high and 3 to 4 feet in diameter at breast height.

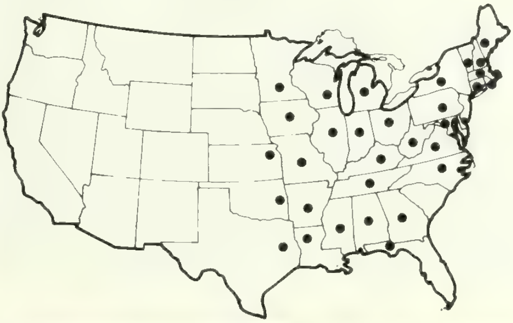
Leaves deciduous, 5 to 9 inches long, 2 to 4 inches wide, seven to nine lobed, deep sinuses, glabrous bright green above, paler below.

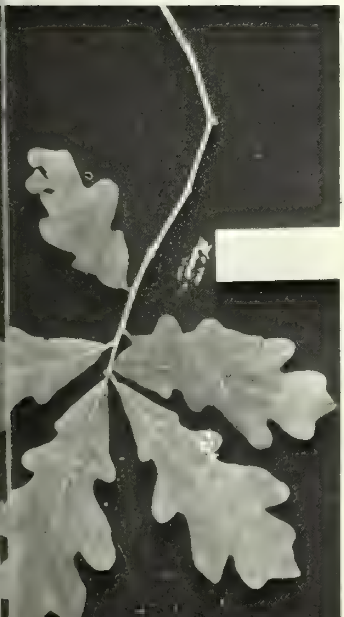
Twigs slender, reddish brown to gray, glabrous, terminal buds 0.19 inch long, leaf scars half-moon shaped.

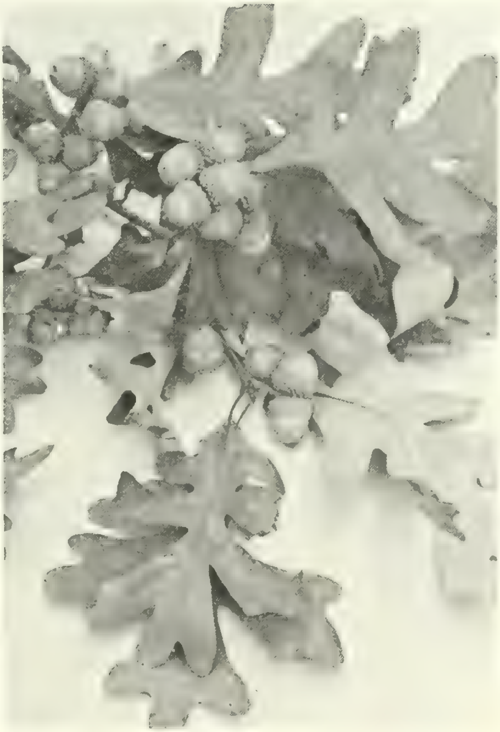
Flowers with leaves April to May.

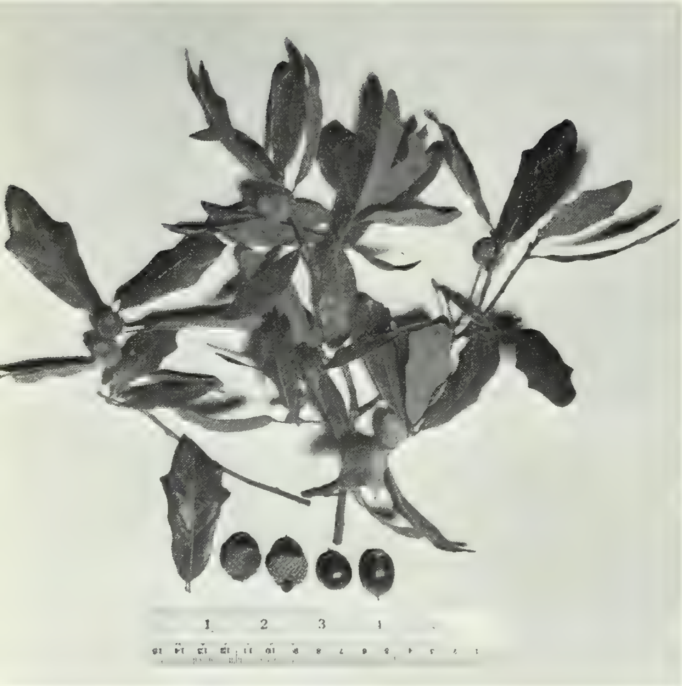
Fruit sessile or short stalked, nut 0.50 to 0.75 inch long, ellipsoid, one-fourth length in bowl-shaped cup. September to October.

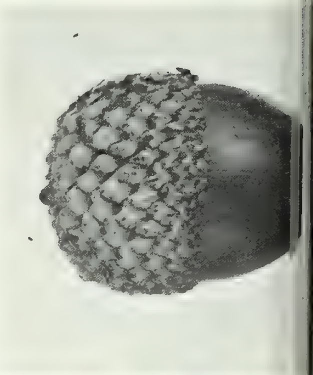












Chapman Oak

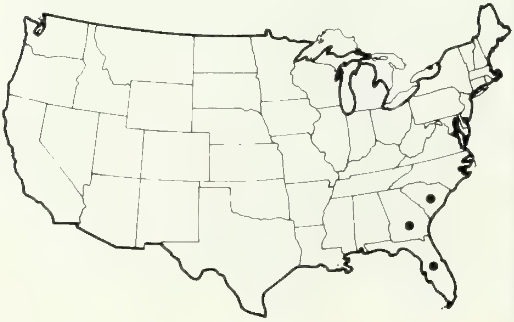
A shrub or small tree up to 25 feet tall, 5 to 6 inches in diameter at breast height.

Leaves dark green, glabrous and lustrous above, light green, or silvery white and glabrous below, 2 to 3 inches long, 1 inch wide, persistent until late winter or spring.

Twigs olive-brown to brownish gray, winter buds ovoid, 0.13 inch long.

Flowers in spring.

Fruit sessile, solitary or paired, nut oval, 0.62 inch long, 0.37 inch thick, but extremely variable in size and shape, pubescent from middle to apex, one-third to one-half of nut enclosed in cups.



Chapman Oak/*Quercus chapmanii* Sarg.

Chapman Oak
A. G. Spratt
Florida Game and Fresh Water Fish Commission
Tallahassee, Florida

Chapman oak grows well on sands and other well drained soils. It is a dominant species in the sand pine scrub community. Growth is sparse under closed canopies of sand pine. Old rank growth predominates in cutover stands of sand pine which have not been regenerated.

Fruiting is most abundant in areas with open to light overstory. Fruit yields are increased when the cutover pine stands are chopped. n Florida sand pine-scrub forest types, acorn yields of Chapman oak ange from 8 to 11 pounds per acre per year.

Acorns of Chapman oak are of primary importance to deer in the and pine scrub. They are also eaten by scrub jays, squirrels, turkeys, nd quail.

Other common names: Chapman white oak, scrub oak, chapman's oak.

Swamp Chestnut Oak*/ Quercus michauxii* Nutt.

Swamp Chestnut Oak
Stephen L. Beckwith
University of Florida
Gainesville, Florida

This species occurs principally on low ground, along river bottoms, or in ravines with other hardwoods.

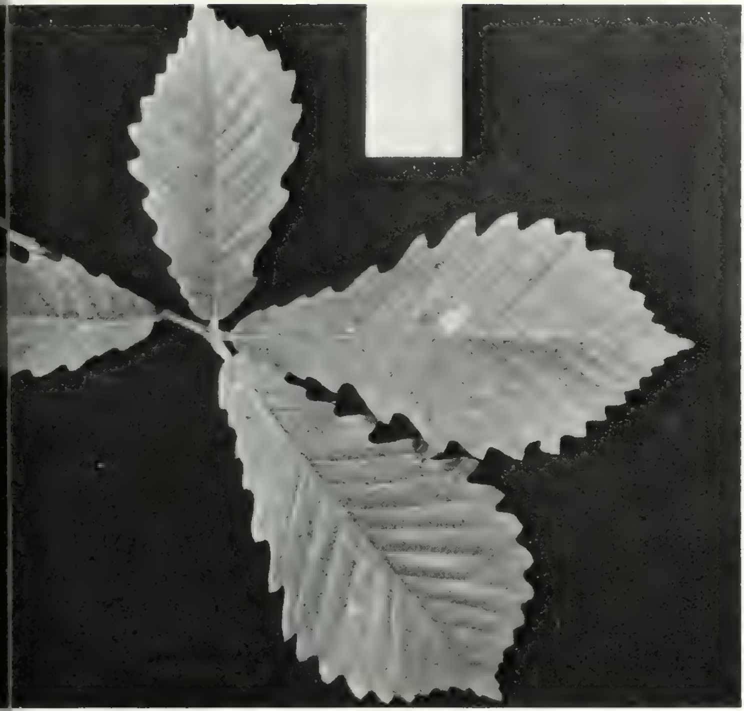
Optimum acorn production begins at about 40 years of age. Germination begins soon after seedfall.

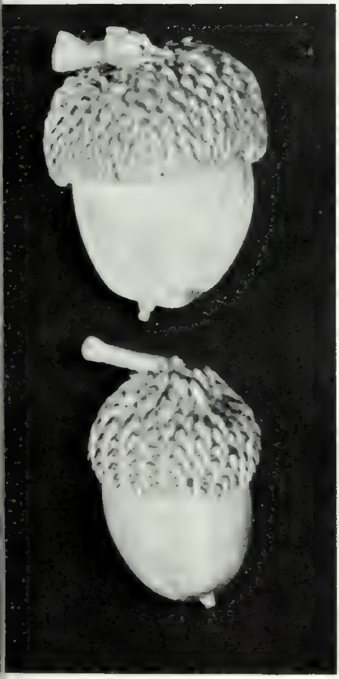
The species is moderately tolerant of shade but easily established in openings. Competition from other species limits early development of swamp chestnut oak seedlings unless they are released by weeding.

Acorn damage from weevils is sometimes heavy, particularly in poor to fair seed years.

The acorn is very palatable but its large size precludes use by most wildlife except white-tailed deer, squirrels, and wild hogs. It can be eaten readily, however, by most wildlife after the shell sheds and germination begins.

Other common names: cow oak, basket oak, white oak.





Swamp Chestnut Oak

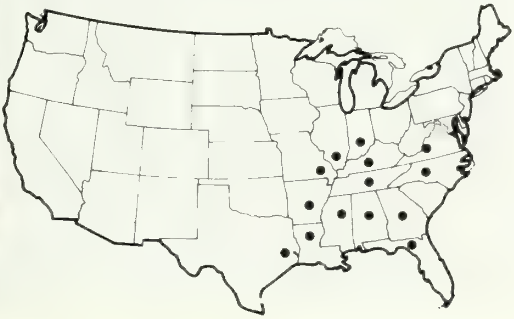
A tree usually 60 to 80 feet tall and 2 to 3 feet in diameter.

Leaves deciduous, 5 to 8 inches long, 2 to 4.50 inches wide, upper surface dark green, lustrous; lower surface pale green to silvery white.

Twigs moderately stout, reddish- to orange-brown, terminal buds 0.25 inch long, covered with thin red scales.

Flowers appear with leaves mostly from April to May.

Fruit 1 to 1.66 inches long, sessile or short stalked, about one-third of acorn enclosed in cup. September and October.



Dwarf Live Oak

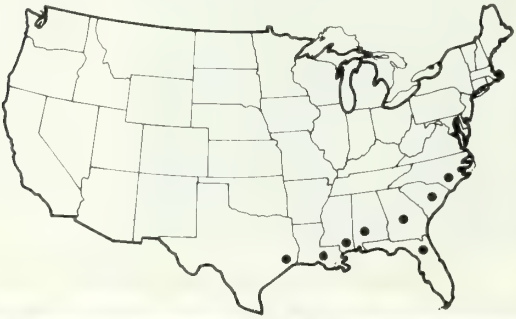
An evergreen shrub up to 3 feet tall, with underground stems.

Leaves evergreen, obovate, toothed, glabrous above, pubescent below, 2 to 5 inches long, extremely variable in size and shape.

Twigs reddish to grayish brown, pith star-shaped in cross section, terminal bud obtuse or rounded, clustered; leaf scars triangular to circular with three bundle scars.

Flowers April and May.

Fruit solitary or several on a long stalk, cup hemispheric, nut ovoid, inner surface of cup hairless, almost indistinguishable from live oak acorns. August to November.



Dwarf Live Oak/*Quercus minima*
Sarg.) Small

ovett E. Williams, Jr.
lorida Game and Fresh Water Fish Commission
ainesville, Florida

warf live oak is found in pine flatwoods, on deep sands behind
each areas, and in seepage areas of sandy-clay uplands on sites
ubject to burning.

It begins to bear fruit at about 4 years of age when grown from seed
the open and usually produces some fruit annually, but the amount
aries considerably. In an east Texas study the maximum acorn yield
ovendry) was 201 grams and the minimum was 3 grams per plant over
6-year period for young plants growing in the open. Plants in the
oods did not bear acorns.

Dwarf live oak is closely associated with fire and often is the only
ak to be found in some large expanses of regularly burned pine flat-
oods. When protected from fire for 5 to 6 years in damp slash pine-
allberry-saw palmetto sites it becomes inconspicuous. But with the
dvent of fire it sprouts and flourishes for a year or two until it is over-
rown by competing plants.

Maximum acorn production is attained when dwarf live oak is
urned in August. In northern Florida, stands burned later than October
il to produce acorns the next summer.

Dwarf live oak acorns are easily germinated by planting them 2
r 3 inches deep in sandy soils as soon as they mature. The plants grow
ell when transplanted by short leaf-bearing underground stem cuttings.
ood cuttings can be obtained during late winter from stands which
ere burned the previous summer.

Chestnut Oak/*Quercus prinus* L.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Chestnut oak grows on dry, sandy, or gravelly soils, and it reaches maximum size in well-drained coves and bottom sites.

Trees begin to produce acorns when about 10 inches in diameter at breast height with optimum yields at about 14 to 24 inches diamete Acorns germinate soon after falling if seedbed conditions are favorabl For artificial planting, the seeds should be gathered as soon as they fa to prevent drying, and stored in sealed containers at 32° to 36°F, or stored in cool cellars.

The tree is intermediate in shade tolerance. Reproduction persist under overhead shade, but the tops will die back and resprout repeate ly unless they are provided full sunlight. Growth is slow. Chestnut oak is susceptible to fire, but it is the most resistant of oaks to heart and sapwood decay.

The chestnut oak acorn is a favorite food of white-tailed deer and gray squirrel, but because of its size it is usually eaten only by large birds such as wild turkey. The leaves are frequently browsed by livestock.

The tree is often planted as an ornamental. The wood is used for posts, tools, baskets, cooperage, boards, veneer, and fuel.

Other common names: rock chestnut oak, rock oak, white oak, c oak, basket oak, Micheaux oak, swamp white oak.

Chestnut Oak

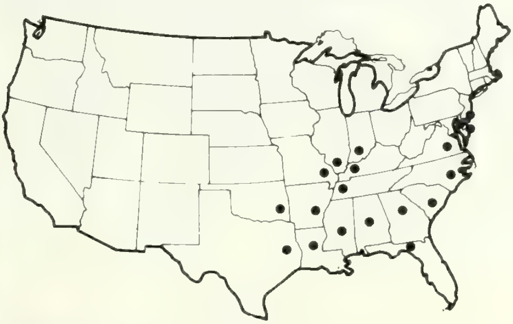
A tree with well formed, straight narrow trunk and narrow crown, 60 to 80 feet high, 2 to 3 feet in diameter at breast height.

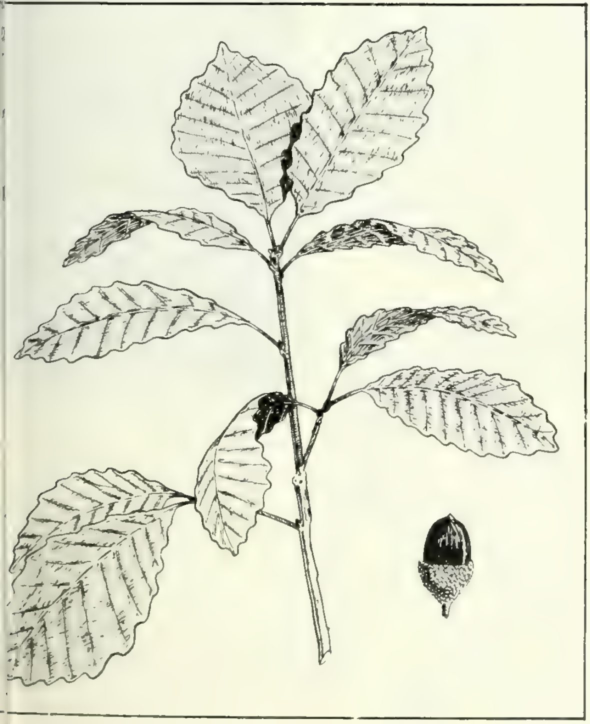
Leaves deciduous, glabrous and lustrous green above, paler and pubescent below, 4 to 8 inches long, 1.50 to 4 inches wide.

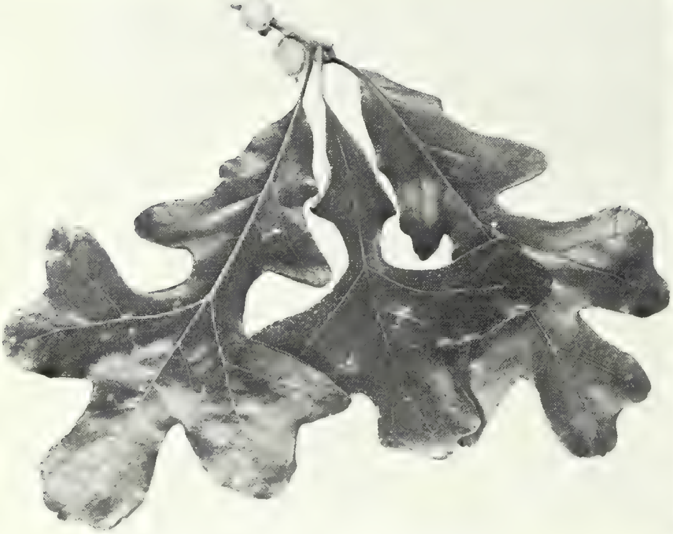
Twigs smooth, reddish-brown to gray later, stout, buds 0.25 inch long, covered with thin, red scales, pale on margin.

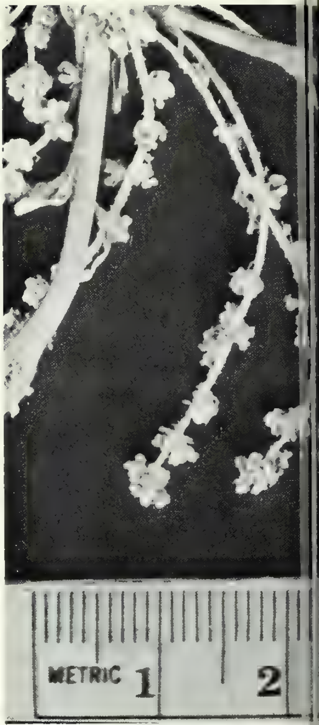
Flowers April to May.

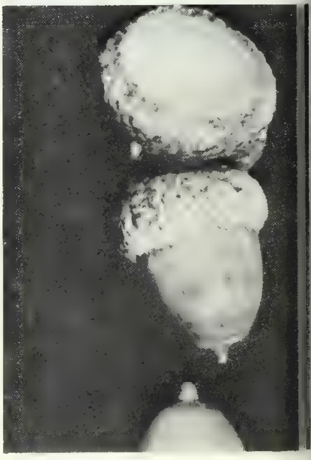
Fruit sessile or stalked, solitary or paired, 0.75 to 1.50 inches long, one-third to one-half of acorn in cup. September and October.











Post Oak

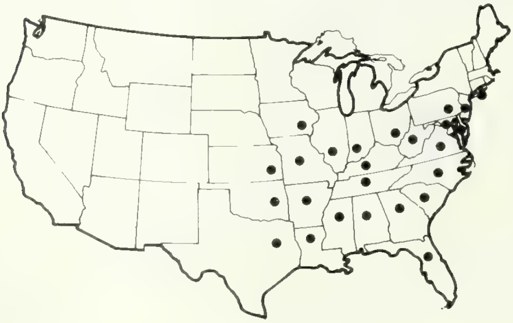
A small to medium size tree, 40 to 50 feet high, 1 to 2 feet in diameter at breast height.

Leaves deciduous, 4 to 7 inches long, 3 to 4 inches wide, five-lobed with deep round sinuses, dark green, rough and glabrous above, paler and tomentose below, leathery and thick.

Twigs brown, stout, buds 0.06 to 0.12 inch long, brown, covered with chestnut-brown pubescent scales.

Flowers March to May.

Fruit sessile or short stalked, solitary or paired or clustered, 0.50 to 0.75 inch long, cup one-half length of acorn, pale and pubescent within, tomentose externally. September to November.



Post Oak/*Quercus stellata* Wangenh.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Post oak grows on a wide variety of soils and on many sites. Typically, it s found on rocky ridges, sandy outcroppings, and southern exposures.

Post oak acorns are eaten by many kinds of birds and mammals and are considered one of the most important sources of food for wild turkeys in the eastern states.

The species is intolerant of shade, but on dry sites it may be a permanent or climax species. Because of its slow growth it is often overtopped by other trees, mostly oaks. However, it tends to persist and become dominant on poor sites because of its drought resistance. In some places it replaces shortleaf pine after repeated wildfires. In Texas, t forms virtually pure stands and invades open prairie after fire protection. Seeds germinate soon after dropping and seedlings develop a thick taproot.

Post oak acorns are heavily attacked by insects.

The wood is used for crossties, fuel, fence posts, furniture, and lumber.

Other common names: iron oak, cross oak, branch oak, rough oak, box oak.

Live Oak/*Quercus virginiana* Mill. var. *virginiana*

Lovett E. Williams, Jr.
Florida Game and Fresh Water Fish Commission
Gainesville, Florida

Live oak is found on a wide variety of soils but most often on sandy soils of recent geologic origin. It is resistant to salt spray and tolerates salinity.

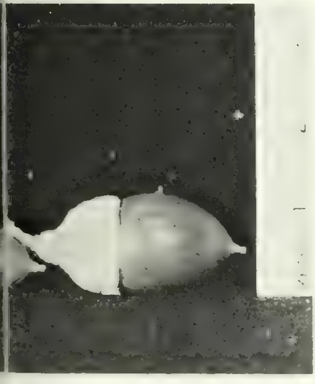
Live oak is a consistent acorn producer. The acorns have a swee flavor, thus they are highly preferred by wildfire. They are the most heavily used acorns by wild turkey in Florida. Few acorns remain viab over winter because a large portion are worm infested.

Seeds germinate soon after falling to the ground under favorabl moisture and temperature conditions. When tops are killed or when t tree is girdled the roots sprout prolifically. The capacity to resprout makes live oak very difficult to kill.

Live oak is harmed by fire and high water but is relatively free of insects and disease. It is very long-lived, even for an oak. Its large spreading branches, short trunk, huge size and draping of spanish mo make the live oak the beautiful symbol of the classical deep South.

The wood is not of much commercial value but may be used for purposes where a hard, dense, rot-resistant and strong wood is required.

Other common name: Virginia live oak.



Live Oak

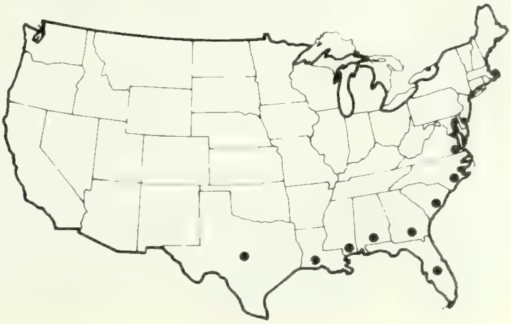
A tree 40 to 50 feet high, 3 to 4 feet in diameter at breast height, with large massive horizontal limbs.

Leaves evergreen, dark green and lustrous above, paler and glabrous to pubescent below, 2 to 5 inches long, 0.50 to 2.50 inches wide, shed in late winter and spring.

Twigs grayish brown, glabrous, terminal buds 0.17 inch long, light brown, leaf scars half-moon shaped.

Flowers March to May.

Fruit in clusters of three to five, nut ellipsoid, 0.33 to 0.50 inch long, one-half enclosed in cup. September to December.



Southern Red Oak

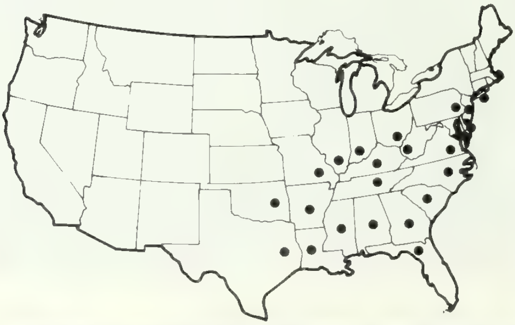
A tree up to 80 feet tall.

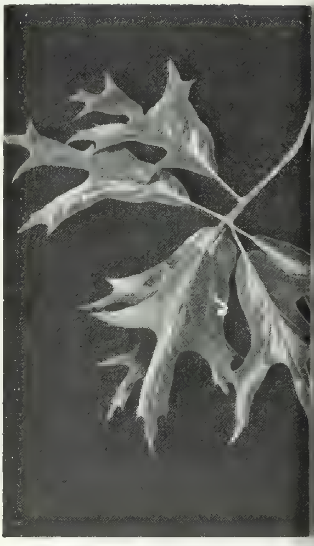
Leaves deciduous, 5 to 9 inches long, 4 to 5 inches wide, three to seven bristle-tipped lobes, dark green and lustrous above, paler with brown beneath.

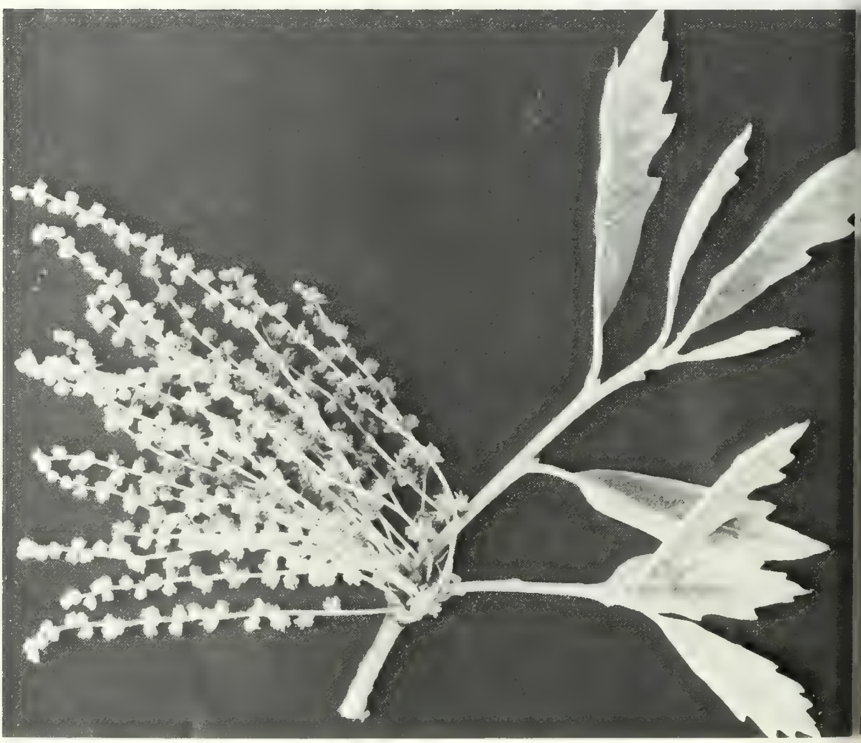
Twigs dark red, pubescent, terminal buds 0.13 to 0.25 inch long, ovoid, reddish-brown scales, stout.

Flowers April to May.

Fruit solitary or in pairs, sessile or short stalk, 0.50 inch long, one-third length in shallow thin cup. September and October.







outhern Red Oak/*Quercus falcata*
ichx. var. *falcata*

owell K. Halls
orest Service, USDA
acogdoches, Texas

outhern red oak usually occurs on dry, sandy, or clay soils, on dry
dgetops, and upper slopes facing south and west. Occasionally it is
und along streams and moist loam slopes. It is commonly associated
th other oaks, hickory, and pines and is rated as intermediate or
tolerant of shade.

Acorns are eaten by many kinds of birds and mammals. Maximum
orn production occurs when trees are 50 to 75 years old. Seeds
rminate in spring. The acorns may be stored in sealed containers for a
ar or two at 32° to 36°F, but it is best to plant immediately when
thered or to stratify at 32° to 38°F for 30 to 45 days before planting.
orns to be sown should never be allowed to dry out.

The tree is susceptible to injury by fire but sprouts vigorously from
e stump when the top has been killed or cut back.

Southern red oak is often planted as an ornamental and the wood
used for general purposes, rough lumber, and furniture. The bark is
cellent for tanning and is used as an astringent in medicine.

Other common names: red oak, Spanish oak, water oak, turkey
ot oak.

***Bear Oak*/*Quercus ilicifolia* Wangenh.**

Burd S. McGinnes
U.S. Fish and Wildlife Service
Blacksburg, Virginia

Bear oak grows on dry, acid, rocky, sandy, sterile soils, especially in pine barrens and on bare rocky mountain tops.

It is an intolerant, light-demanding species that follows clear-cutti or fire. It has the ability to grow upon exposed and inhospitable sites where it serves as a "cover tree" until displaced by more valuable timb species. Since it often grows in thickets and monopolizes the site it is often considered a nuisance in timber regeneration.

Bear oak usually produces good crops of acorns annually; thus, i is a dependable source of food for many game species and songbirds. The acorns are small and are eaten by many of the smaller birds, particularly jays and woodpeckers. Deer browse on the foliage and tw

Stratified seeds may be sown in the spring, or fresh seeds in the f at the rate of 2 pounds per 100 square feet. The seed should be covered with one-half to one inch of firmly packed soil.

Trees begin to bear acorns at an early age when grown from sprouts; the optimum yields occur at 5 to 8 years. After trees are 8 ye old the acorn yields decline, but plants 24 years old have continued t produce acorns.

Sprout production can be increased by cutting stems to the grou and by fire.

Other common names: scrub oak, black scrub oak, turkey oak, j oak, redbrush.

Bear Oak

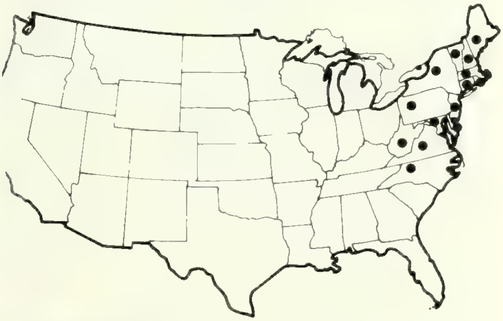
A much-branched straggly shrub or small tree 3 to 10 feet but may reach 20 feet tall, trunk up to 5 or 6 inches in diameter at breast height.

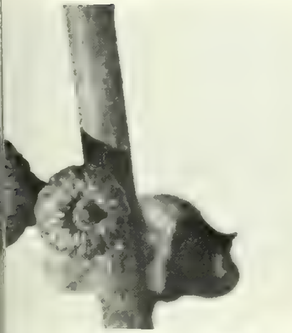
Leaves with three to seven shallow sinuses, dark green above, whitish-felted beneath, 2 to 5 inches long, 1.50 to 3 inches wide.

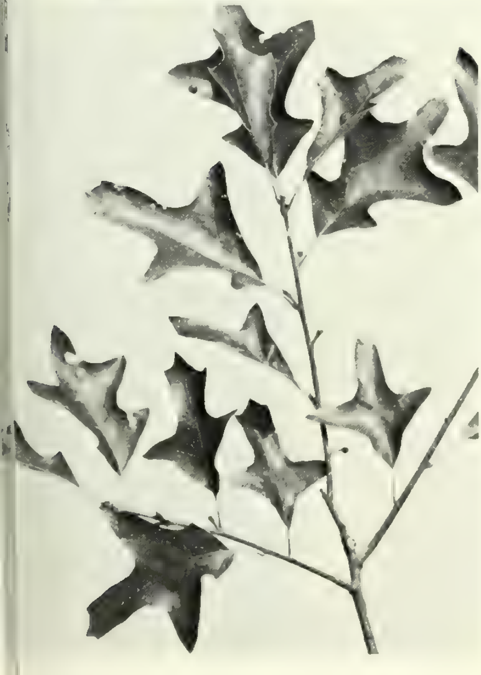
Twigs tinged with red and pubescent at first, becoming glabrous and darker in second year, and ultimately dark brown or black; winter buds blunt, 0.12 inch long, dark chestnut brown.

Flowers appear before or with leaves.

Fruit produced in great profusion, sessile or stalked, in pairs or solitary, nut ovoid, broad flat at base, 0.50 inch long, half the length in bowl-shaped cup. September and October.







Bluejack Oak/*Quercus incana* Bartr.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

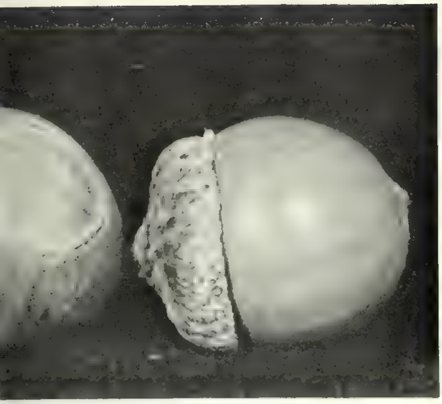
Bluejack oak grows on dry sandy ridges, pine-barrens, and dunes in
Coastal Plain often in association with turkey oak.

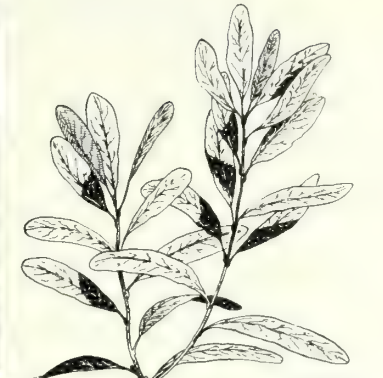
Acorns are first produced when trees are about 2 inches in diameter at breast height with optimum yields at 4 to 8 inches diam
It is one of the highest acorn yielders per square foot of basal area. Yields are quite consistent from year to year.

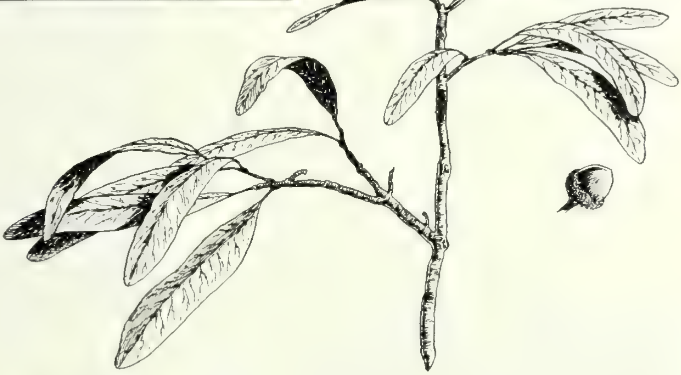
It is recommended that this oak be retained on dry sandy ridge
since bluejack is one of the few oak species that grows well on sites
a low site potential to grow timber. It grows well as an understory tr
longleaf pine stands, giving little competition to the pine.

Bluejack oak is of little commercial value except for firewood a
fence posts.

Other common names: sand jack, cinnamon oak, shin oak, up
willow oak, turkey oak.







Bluejack Oak

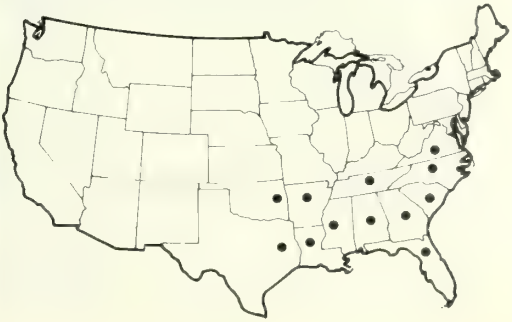
A shrub or small tree up to 35 feet high.

Leaves deciduous, entire, grayish green, densely tomentose beneath, smooth above, 2 to 5 inches long, 0.50 to 1.50 inches wide.

Twigs heavily tomentose when young, gray to dark brown when older.

Flowers in spring.

Fruit sessile or short stalked, globose, brown to blackish with grayish pubescence, 0.50 inch long, cup one-third of length.



Laurel Oak

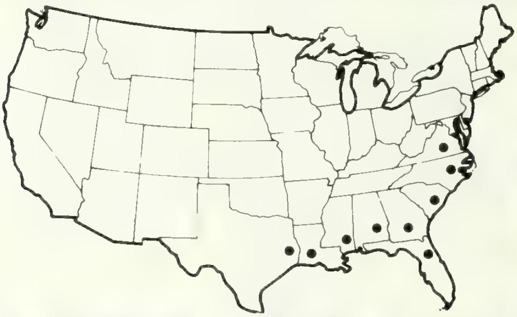
A tree 60 to 70 feet high, 2 to 3 feet in diameter at breast height.

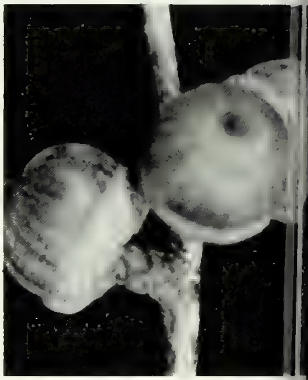
Leaves semi-evergreen in South, deep shiny green and glabrous above, paler and lustrous beneath, 2 to 6 inches long, 0.50 to 1 inch wide.

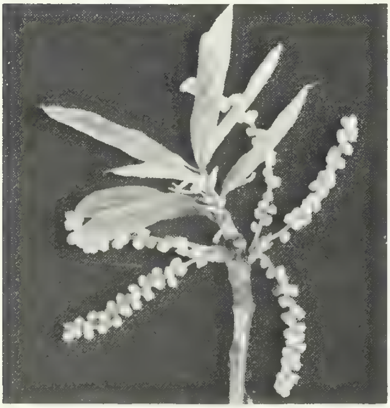
Twigs slender, dark red, glabrous, terminal buds 0.10 to 0.12 inch long, covered with lustrous, red-brown scales.

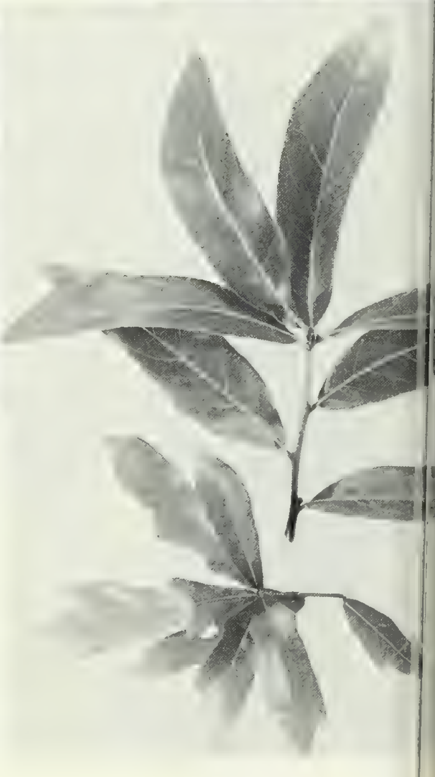
Flowers February and March.

Fruit solitary and sessile, 0.50 inch long, one-fourth length in cup. September and October.









Laurel Oak/*Quercus laurifolia* Michx.

tephen L. Beckwith
niversity of Florida
ainesville, Florida

his relatively short-lived oak occurs commonly along streams, river ottoms, and on the better moist upland soils. It is fairly tolerant of hade, but is not considered a climax species. It often becomes stablished and grows up through the dense canopy of a swamp border. is damaged by fire.

The trees usually mature in about 50 years. When cut or burned, urel oaks produce many sprouts from the base of the stump, and ome old trees produce sprouts from their roots.

The tree is often planted as an ornamental. The wood is mostly sed for fire wood.

Other common names: Darlington oak, obtusa oak, diamond-leaf ak, swamp laurel oak, laurel-leaved oak, water oak.

Blackjack Oak/*Quercus marilandica* Muench.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

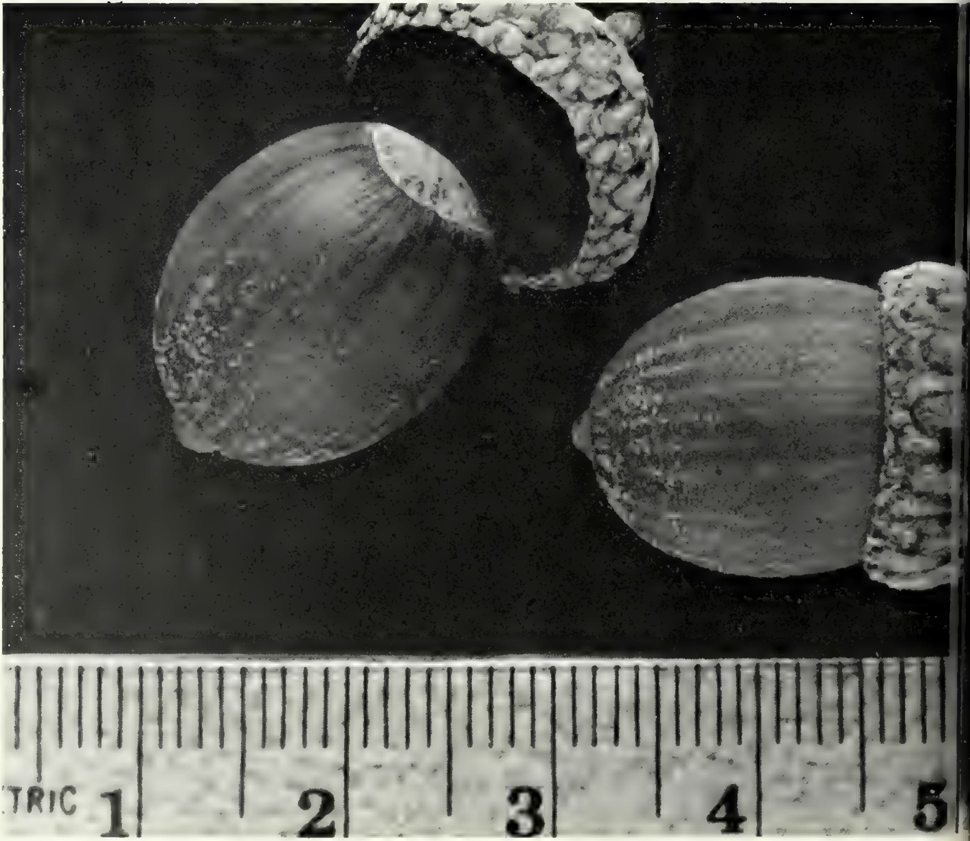
Blackjack oak usually grows on dry, sandy, sterile soils in association with bluejack oak.

Trees begin to bear acorns when about 8 inches in diameter at breast height and reach optimum production at about 16 inches.

The tree has little commercial value and is often poisoned in tim stand improvement operations. Squirrels prefer the nuts over those o most other red oaks.

The wood is used mostly for posts, fuel, and charcoal.

Other common names: blackjack, barren oak, black oak, jack oa



Blackjack Oak

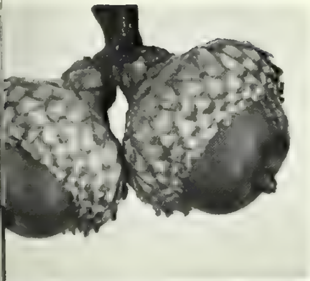
A small poorly formed tree up to 60 feet tall and 2 feet in diameter at breast height.

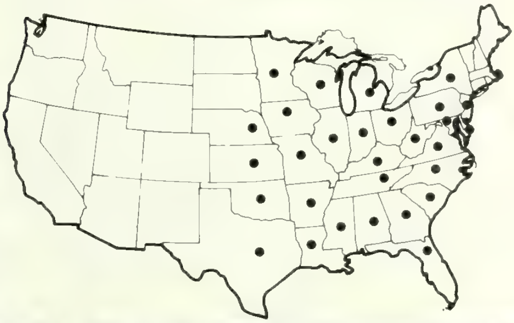
Leaves deciduous, stiff, bristle tipped; upper surface dark green, glossy, glabrous; lower surface, scurfy and yellow hairs; 3 to 7 inches long, 2 to 5 inches wide.

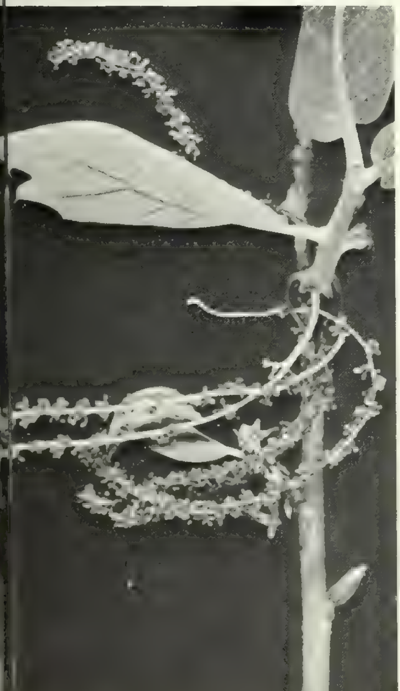
Twigs grayish brown, stout, glabrous; buds 0.17 to 0.33 inch long, reddish-brown, densely tomentose.

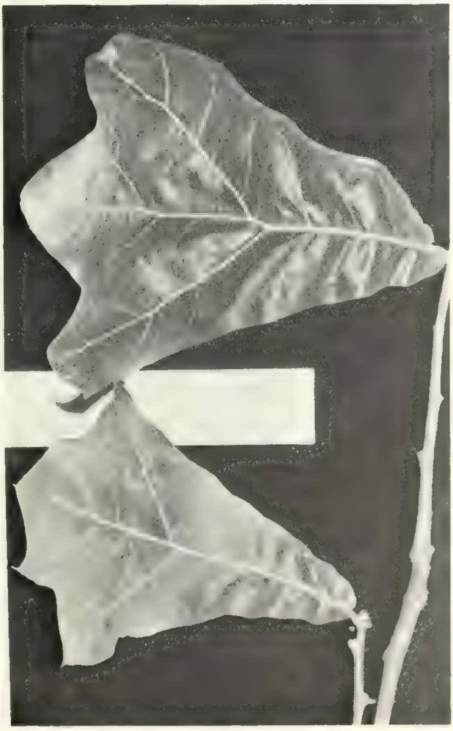
Flowers with leaves in spring.

Fruit 0.60 to 0.80 inch long, in pairs or solitary, sessile or on short stalk, light brown, one- to two-thirds in cup. September and October.









Water Oak

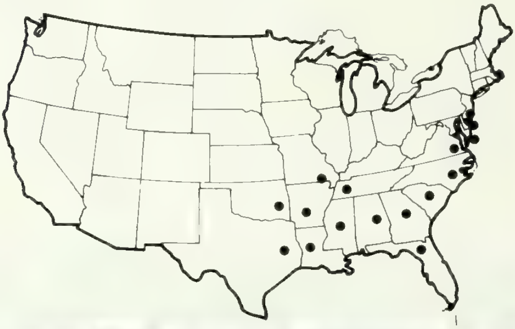
A tree 60 to 70 feet tall, 2 to 3 feet in diameter at breast height.

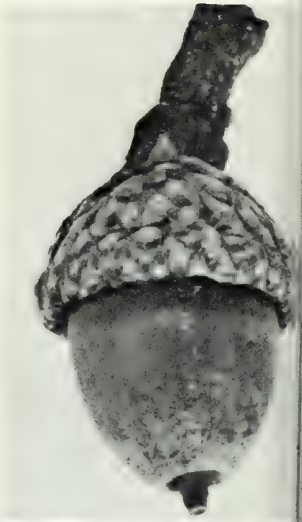
Leaves persistent, variably shaped, entire, bristle tipped, blades 2 to 4 inches long, 1 to 2 inches wide, upper surface lustrous green, lower surface lighter.

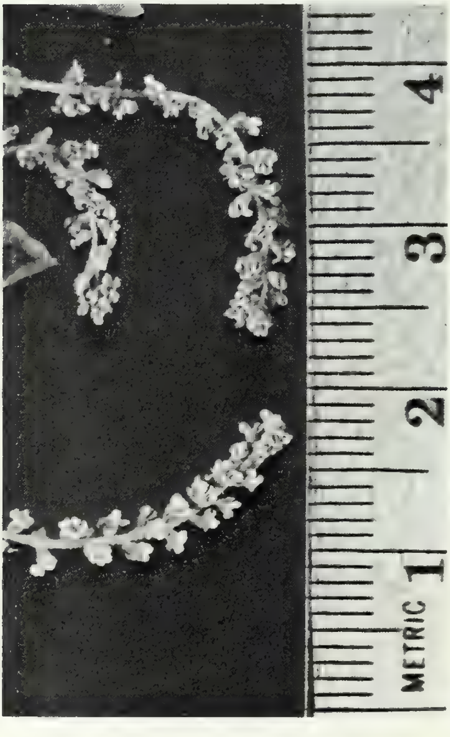
Twigs slender, glabrous, reddish gray; buds ovoid, reddish brown, 0.13 to 0.25 inch long.

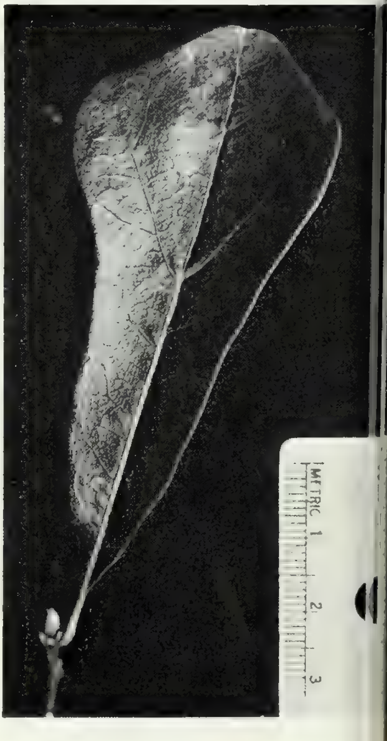
Flowers with or shortly before leaves in spring.

Fruit sessile or short stalked, solitary or paired, 0.33 to 0.67 inches long, one-third to one-half enclosed in shallow cup. September and October.









Water Oak/*Quercus nigra* L.

ryant A. Bateman
ouisiana State University
aton Rouge, Louisiana

Vater oak is found along small streams, on the margins of swamps, on ottomlands, and on deep or moist upland soils, including pine atwoods in Florida. The best sites are alluvial bottoms, the better-rained silty clay or loam ridges, and the borderlines between flats and dges.

The tree is intolerant of shade. It grows fast but is relatively hort-lived. On good Delta sites it may reach a diameter of 4 feet in 75 ears and then is likely to deteriorate.

Good acorn crops are borne nearly every year. Mature trees may roduce one-quarter to one and one-half bushels of fruit per year. In ouisiana, water oak is the most dependable producer among the oaks. roduction in the Mississippi Delta averaged almost 45 pounds per tree ver a 10-year period. Seeds germinate the spring after seed fall. Seeds erminate well under moderate shade, but seedlings must be released to ontinue growth. Early height growth on good sites is about 2 feet per ear for the first 25 years. Water oak can withstand considerable ooding, but complete prolonged submergence during the growing eason will kill the trees.

The tree is susceptible to fire at all ages.

Acorns are readily eaten by deer and by squirrels. Most acorns have ropped by December.

Water oak is extensively planted as an ornamental. The wood is sed for firewood, crossties, and poles.

Other common names: possum oak, red oak, spotted oak, bluejack ak, duck oak, pin oak, barren oak.

***Nuttall Oak**/Quercus nuttallii* Palmer

Bryant A. Bateman
Louisiana State University
Baton Rouge, Louisiana

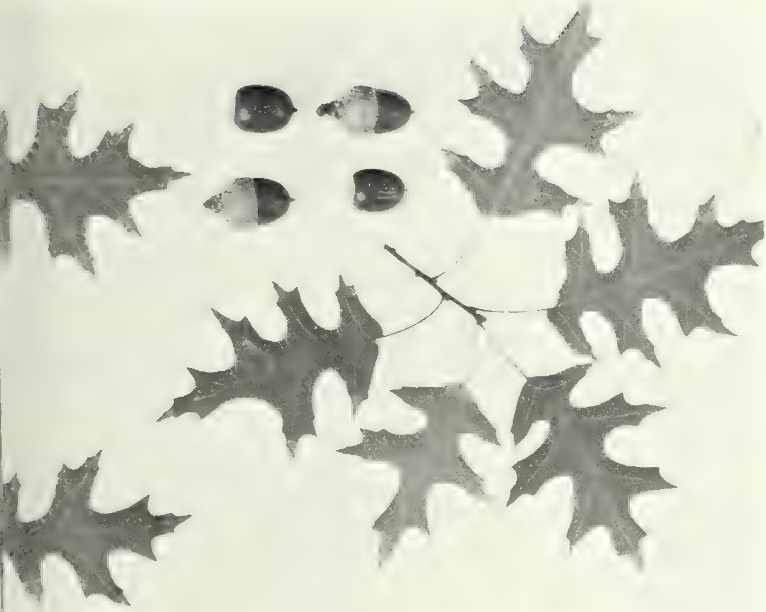
Nuttall oak is mid-tolerant of shade and grows on the poorly draine first and second bottoms. Typically, it grows on clay flats that are normally covered with 3 to 8 inches of water throughout the winter.

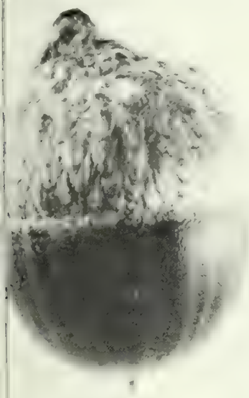
Optimum acorn production begins when trees are about 20 ye old. The average tree yields one-quarter to one and one-half bushel clean nuts. The seeds germinate the spring after maturity. Seedlings become established both in the open and in the shade, but they ca survive in the shade. Oftentimes, the seedlings are killed by high wa during the growing season. The trees grow rapidly and are nearly al dominant or codominant in the stand.

In Louisiana, deterioration sets in soon after trees reach 20 inc in diameter at breast height; however, sound vigorous trees over 30 inches in diameter have been found in Arkansas.

In Louisiana Nuttall oak is considered one of the best mast-producing species. Acorn crops rarely fail, and many acorns remain the trees in January. During periods of winter flooding squirrels fin ready supply of acorns still on the trees. Acorns are also favored by and are available to turkey. Quail will use broken parts of the large acorns, but the Nuttall site is very poor quail habitat.

Other common names: red oak, smooth-bark red oak, tight-ba red oak, yellow-butt oak, striped oak, pin oak.





Nuttall Oak

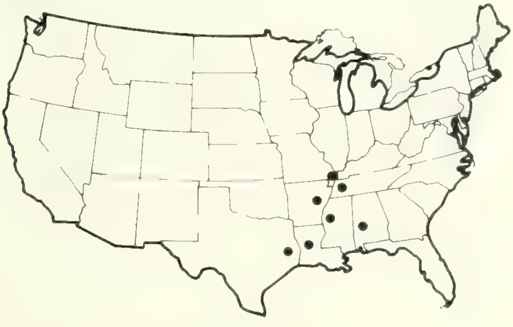
A medium sized tree, up to 100 feet high and 3 feet in diameter at breast height, strongly buttressed when old.

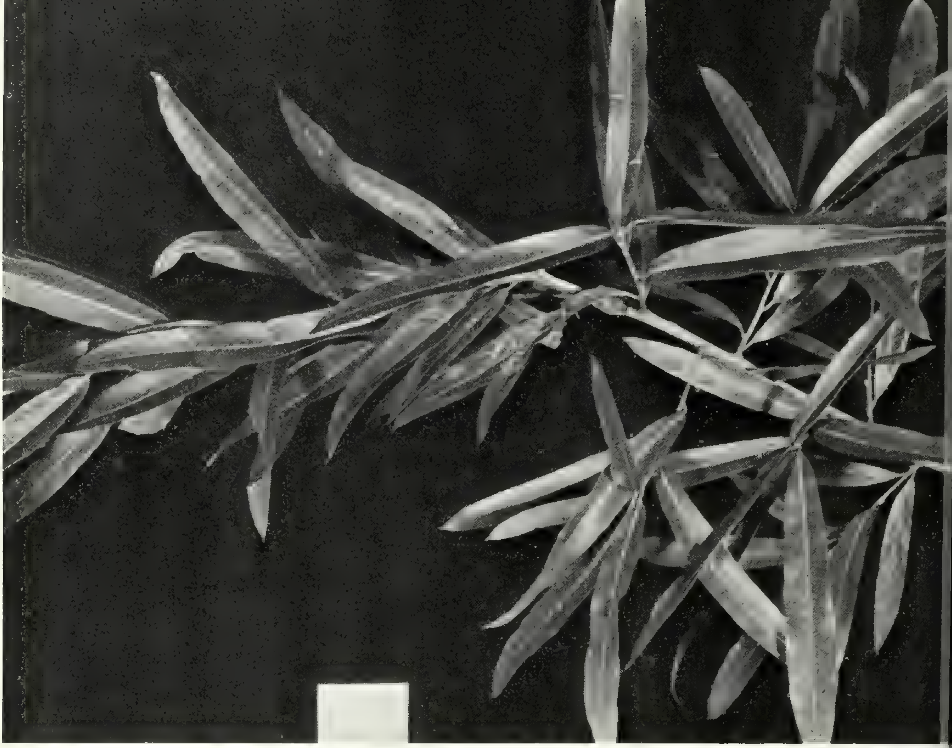
Leaves deciduous, five to seven lobed, two to five bristled teeth on each lobe, blade 4 to 8 inches long, 2 to 5 inches wide; upper surface dull, dark green, lower pale.

Twigs glabrous, olive green to reddish brown when young, gray when older, bud 0.25 inch long, gray-brown scales.

Flowers March to May.

Fruit sessile or short stalked, 0.75 to 1.33 inch long, 0.50 to 1 inch wide, one-fourth to one-half of length in a cup; cup continued into a conspicuous neck at the base. September to February.





Willow Oak

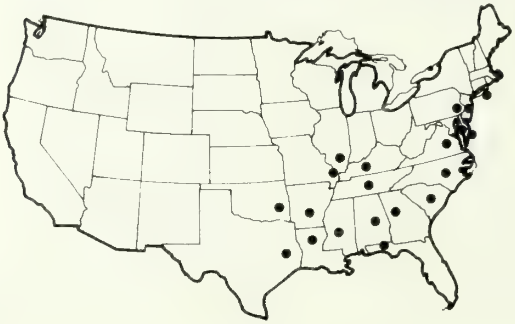
A large tree 80 to 100 feet high, 3 to 4 feet in diameter at breast height.

Leaves deciduous, linear, light to dark green and glabrous above, lower surface paler and glabrous, blade 2 to 5 inches long, 0.33 to 1 inch wide.

Twigs reddish-brown and pubescent first, later gray and glabrous, buds brown, ovoid, 0.08 to 0.17 inch long, glabrous scales.

Flowers February to May, shortly before trees leaf out.

Fruit solitary or in pairs, sessile or short stalked, acorn 0.40 to 0.60 inch long, as broad as long, one-quarter of nut in cup. August to October.



Villow Oak/*Quercus phellos* L.

owell K. Halls
orest Service. USDA*
acogdoches, Texas

illow oak grows on many alluvial soils. Site quality decreases from gher to lower topographic positions, and in the Mississippi Delta it ecreases with increase of clay in the soil.

Mature trees produce 0.25 to 1.50 bushels of acorns per tree. eeds germinate the spring after seedfall. Early height growth is oderate. Prolonged submergence during the growing season is fatal.

Willow oak is a subclimax tree. It is intolerant of shade, but all cept suppressed trees of poor vigor respond well to release. It is sceptible to damage by fire. Trees not killed by fire are frequently ounded and open to serious butt rot. It sprouts readily from young umps.

The tree is often planted as an ornamental. The wood is of lesser lue than other commercial oaks but is used for fuel, charcoal, and neral construction.

Other common names: peach oak, pin oak, red oak, water oak, amp oak, swamp willow oak.

Running Oak/*Quercus pumila* Walt.

Lovett E. Williams, Jr.
Florida Game and Fresh Water Fish Commission
Gainesville, Florida

Running oak is found in pine flatwoods and open sandy pine-oak s
and forms loose thickets from underground stems. It is a member o
subclimax fire community and is the only described species of the "
oak" group in the southeastern U. S. that matures its acorns from flowers in a single year.

This species does not compete with pine for sunlight. It is slow-spreading and does not become a serious weed problem. It fruits h
the summer after a summer burn.

Acorns growing on the short shrub are available to wildlife bef
maturity, but under normal circumstances wild hogs, turkeys, deer, squirrels, crows, and other wildlife do not eat the acorns until they
nearly mature and easily popped from the cup.

Other common name: ground oak.

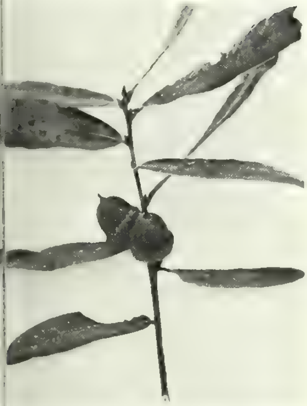
Running Oak

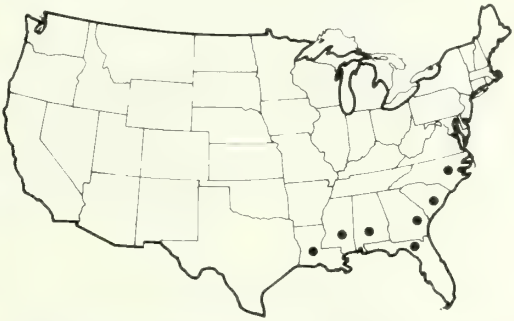
A thicket-forming shrub, 2 to 8 feet tall, with large underground stems. In undisturbed habitat the thickets may be 50 feet in diameter.

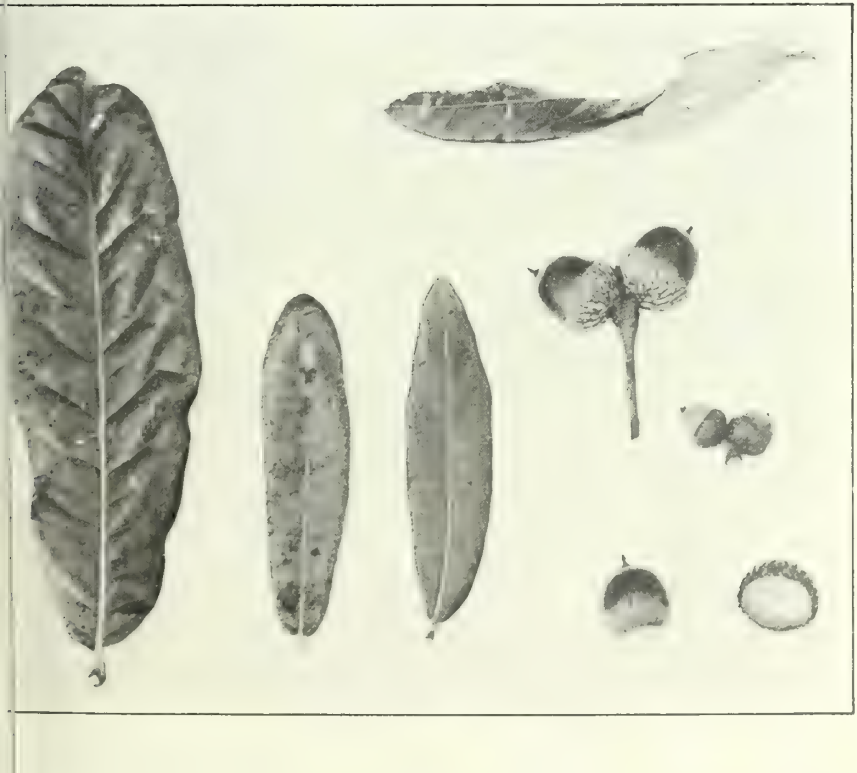
Leaves abscise in late winter or spring, thin, leathery, glabrous above, usually grayish and soft tomentose below, 2 to 6 inches long.

Twigs reddish brown to brown with star-shaped pith, leaf scars triangular to half round with three bundle scars, buds pointed, with long subtending bracts.

Fruit sessile or nearly so, cup saucer-shaped, inner surface of cup hairy, seed scar orange to gold colored, acorn brownish to black. July to October.







Northern Red Oak/*Quercus rubra* L.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Northern red oak grows in soils ranging from clay to loamy sands, an from deep, stone-free to shallow, rocky soils. It is found most frequen on northern and easterly aspects, lower and middle slopes, coves, an ravines.

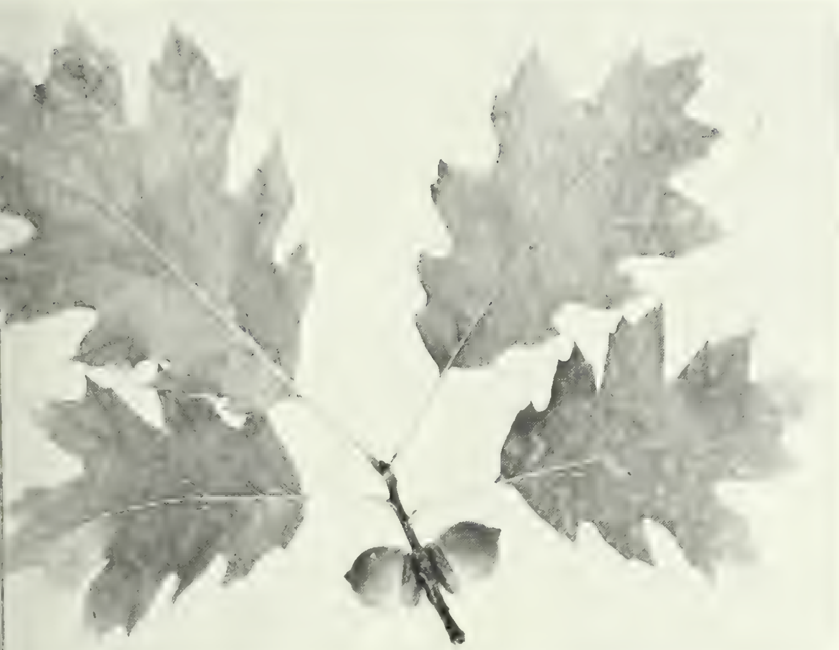
Acorn production is optimum when trees are 50 to 125 years ol Yields of approximately 8 pounds per square foot of basal area can b expected from trees 18 inches in diameter at breast height. The acor are bitter and do not seem to be eaten by wildlife as much as some o the other oaks.

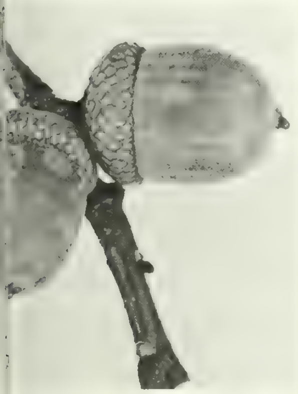
Acorns germinate the spring after seedfall. Germination is follow by vigorous and rapid taproot development that enables the seedling to withstand much dryness while still very small.

The species is intermediate in tolerance to shade and responds to release. It grows rapidly, sprouts from the trunk freely, is long-live but is easily damaged by fire and subject to beetle and fungus attack especially heart rot.

The tree is widely planted as an ornamental. The wood is used furniture, interior finishing, crossties, posts, mine timbers, and genera construction. The wood is considered to be better than that of other oaks but not as good as that of white oak. It has a tendency to chec split, and shrink and is difficult to dry.

Other common names: gray oak, common red oak, eastern re oak, mountain red oak, red oak.





Northern Red Oak

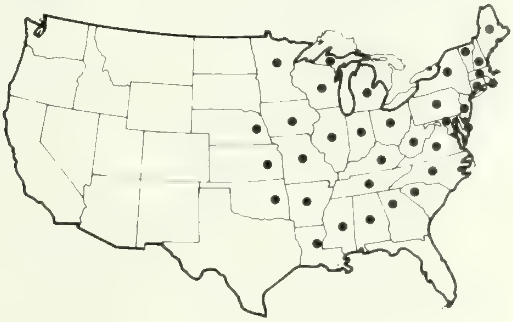
A medium sized tree 60 to 70 feet high, 2 to 3 feet in diameter, short massive trunk.

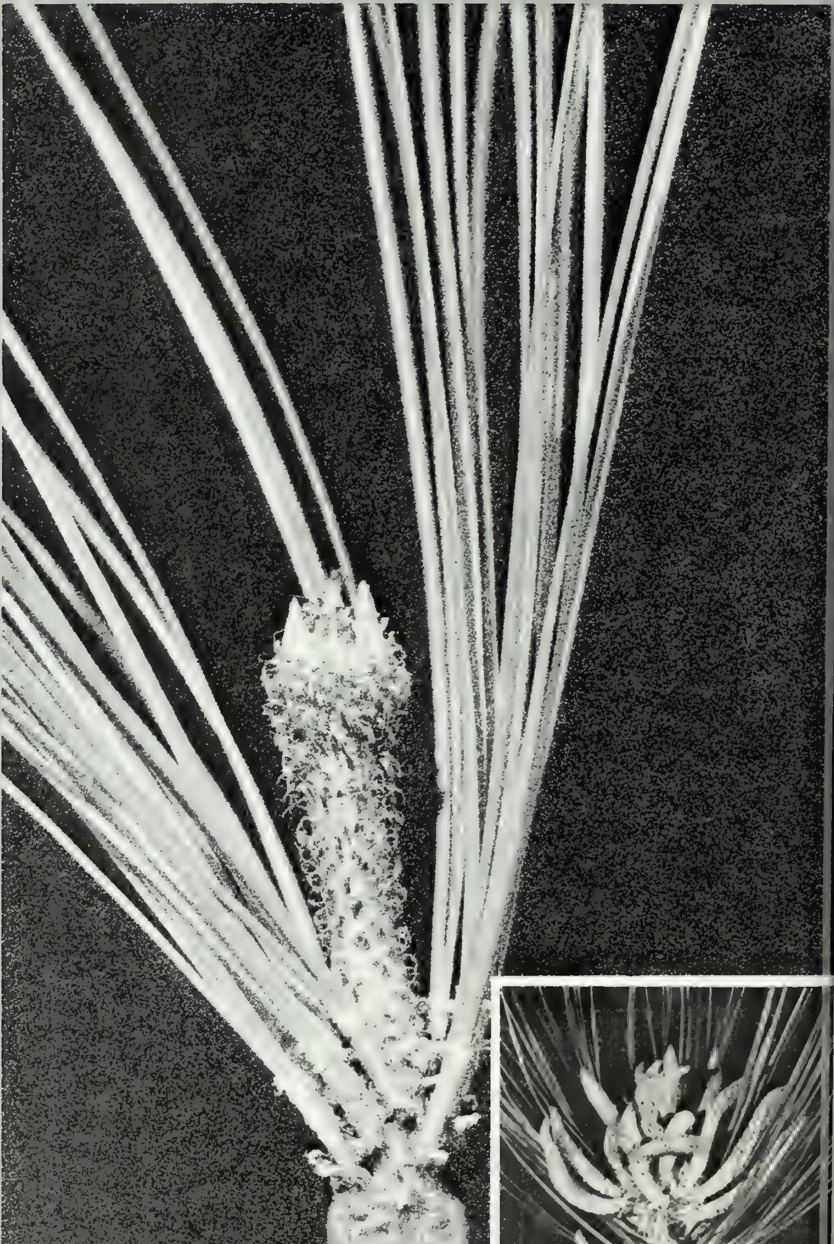
Leaves deciduous, blades 5 to 9 inches long, 4 to 6 inches wide, margin has 7 to 11 lobes that extend halfway to midrib, upper surface dull, dark green, smooth, glabrous, lower surface paler and glabrous.

Twigs green to reddish brown, lustrous, glabrous, stout, pith star-shaped, terminal buds brown, ovoid, glabrous or somewhat pubescent, 0.25 inch long.

Flowers May to June.

Fruit solitary or paired, sessile or short stalked, 1 to 1.25 inch long, cup at base of acorn, saucer shaped, 0.50 to 0.75 inch thick. October to November.





Cone & Conelik

CONE AND CONELIKE

A cone is a multiple fruit with overlapping scales. Seeds are the edible portion of the fruit, and they are eaten by many kinds of wildlife and occasionally by humans.

Seeds from the cones of pines are high in crude protein, crude fat, crude fiber, and phosphorus. Seeds of magnolia are very high in crude fat, and moderate in crude protein, phosphorus, and calcium.

Southern Magnolia/*Magnolia grandiflora* L.

Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

Southern magnolia grows best in moist well-drained soils along strea or near swamps in the Coastal Plain, and in low, moist sites in uplan areas. It is considered climax in the southeastern coastal maritime zo It is usually associated with a large variety of moist-site hardwoods bu cannot withstand prolonged inundation. It endures considerable sha when young, but needs more sunlight as it becomes older.

The seeds are a favorite food of squirrels. They are also eaten b other rodents, many songbirds, opossums, bobwhite quail, and wild turkey.

Magnolia produces prolific crops of seeds annually. There are 4 60 seeds per cone.

The wood is used for fuel, baskets, crates, woodenware, and furniture.

The tree is widely cultivated for its beautiful flowers and showy leaves.

Other common names: bull-bay, evergreen magnolia, great lau magnolia.

Southern Magnolia

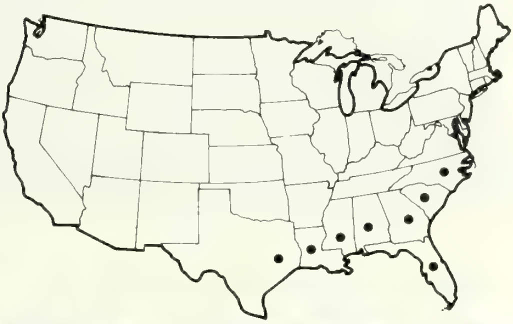
A large tree, usually about 50 feet tall but may reach 100 feet or more, 2 to 3 feet in diameter at breast height.

Leaves evergreen, coreaceous, shiny and dark green above, rusty-tomentose beneath, 4 to 9 inches long, 2 to 3 inches wide.

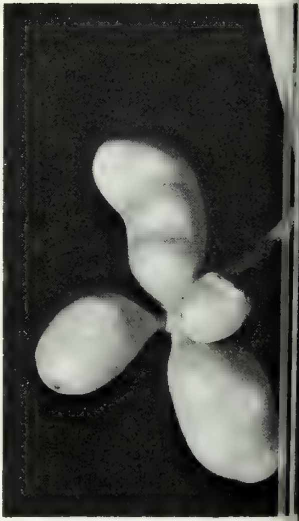
Twigs green to olive, stout.

Flowers white, often purple at base, wax-like, fragrant, 6 to 8 inches across. April to August.

Fruit conelike, rose-colored, rusty-hairy, with several one- to two-seeded fleshy follicles, 2 to 4 inches long, 1.50 to 2 inches wide. July to October.



Sweetbay



Large shrub or small tree up to 35 feet tall.

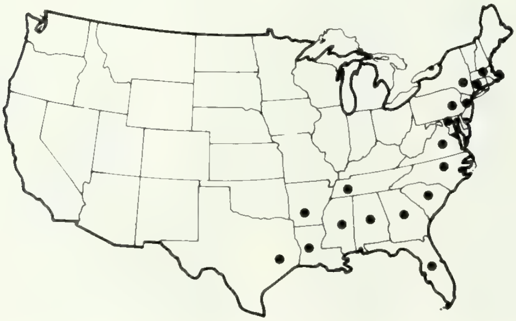
Leaves alternate, tardily deciduous in North or persistent; leathery, pungently aromatic, 3 to 6 inches long, 1 to 2.50 inches wide. Upper surface dark green, lower chalky white and often silky.

Bark gray, smooth or slightly furrowed on older plants, aromatic, bitter.

Twigs slender and bright green. Winter buds covered with fine silky pubescence.

Flowers white and fragrant, 2 to 3 inches broad. May to June.

Fruit a cone like aggregate of small to ovoid follicles, yellow or reddish when ripe. September.



weetbay/*Magnolia virginiana* L.

obert Kral
rginia Polytechnic Institute and State University
acksburg, Virginia

veetbay is common on sites that are poorly drained or often flooded. ich sites are usually acid, but the species also grows in alkaline soils of vines and hammocks.

It tolerates shade but is favored by logging of a swamp forest. rainage and lowering of the water table may limit sweetbay to aterways. Burning of the shrub bogs causes sweetbay and many of its sociates to be replaced by cane stands or by saw-palmetto in the ngleaf and slash pine types. An increase of organic matter in the form muck may reduce or eliminate sweetbay from the shrub bog.

Sweetbay somewhat resembles southern magnolia (*M. grandiflora*), loblolly-bay [*Gordonia lasianthus* (L.) Ellis], and redbay [*Persea* *rbonia* (L.) Spreng.]. It may be quickly distinguished by the startling hiteness of its under-leaf surfaces.

The seeds are readily eaten by squirrels, and lightly by other small ammals, songbirds, wild turkey, and bobwhite quail.

The leaves and twigs are browsed all year. Utilization by deer is nerally moderate to heavy, depending on whether plants are undant or scarce. In Florida forests where production was 115 pounds r acre, 38 percent of current growth was taken.

Cattle compete strongly for sweetbay. In winter 25 percent of their et may consist of sweetbay browse.

Its persistent leaves, fragrant white flowers, and decorative fruit ake sweetbay attractive to gardeners.

Plants usually produce some fruit annually but the yields are small. eds drop from cone soon after maturity.

Other common names: swampbay, sweetbay magnolia, whitebay, ergreen magnolia, laurel magnolia, swamp magnolia, southern eetbay.

Pines*/Pinus* spp.

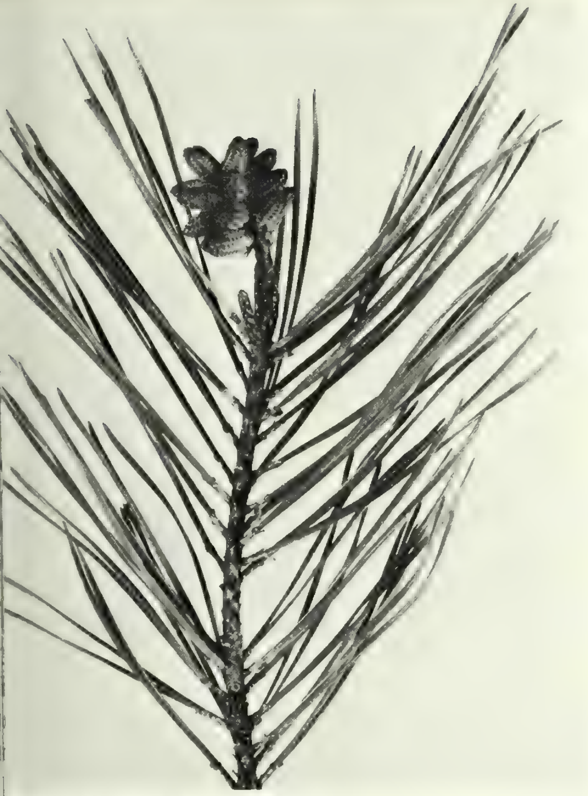
Lowell K. Halls
Forest Service, USDA
Nacogdoches, Texas

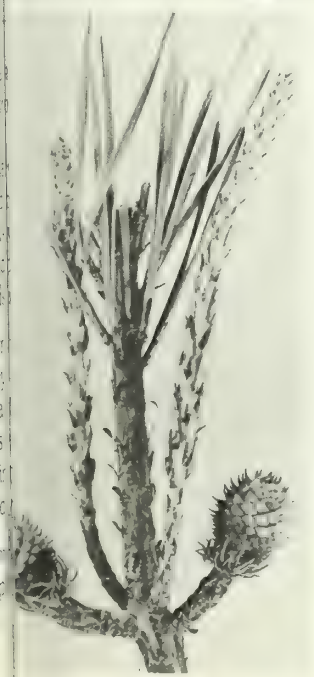
Pines are closely linked to wildlife and habitat values in the South. In some cases the relationship between pines and wildlife is benefic and at other times conflicting. For example, pine seeds furnish foo many kinds of birds and small mammals. The seeds are second on the oaks in importance as food to wildlife. Pine seeds are especiall important to birds in the coastal pinelands and consumption may b heavy as to jeopardize both natural and artificial regeneration of pi seedlings. Pine seed depredation can be averted on direct-seeded by treatment with repellents. In open-grown pine stands the associa species may provide valuable food and cover for many kinds of wil but in extensive dense stands wildlife activity may be extremely limi Young pines may be seriously damaged by some species of wildlif Cottontail rabbits and possibly swamp rabbits often sever stems of planted seedlings. Eastern pocket gophers may eat the roots of pi they encounter in tunneling and may pull small pines into their tu Deer may damage seedlings, especially newly planted seedlings in late winter.

Pinelands are the chief habitat for some birds such as the pin warbler, brown-headed nuthatch, and Bachman's sparrow. Old-gro stands are indispensable to the existence of the rare red-cockaded woodpecker. Pine needles are eaten by grouse. The evergreen foli year-around wildlife cover. Larger pine trees are favorite roosting p for many birds, including the robin, wild turkey, and mourning do Such trees serve as nesting sites for the bald eagle and mourning Pine needles are used as nesting materials by several kinds of bird

Pines are monoecious. Male cones are borne in late winter or spring in clusters at the tips of the preceding year's branches. They elongate-cylindric, mostly dangling, and consist of numerous spiral arranged stamens. They wither after pollen is shed. Female cones borne on newly emerging shoots just forward of a cluster of stami cones. After pollination the ovulate cones become hard and wood

The winged or wingless seeds of pine are borne in woody co that mature at the end of the second year. They may shed promp or remain attached to the tree, sometimes not opening.





Sand Pine

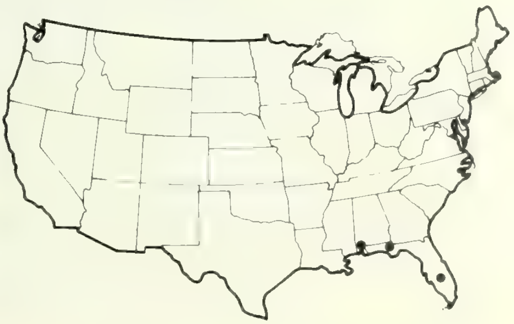
A tree up to 60 feet high, usually with crooked bole.

Needles in two's, 3 to 4.50 inches long, slender, flexible.

Twigs smooth and slender, much branched.

Flowers December and January.

Mature cones 2 to 4 inches long, persistent and unopened for many years, short, prickless. October.



Shortleaf Pine

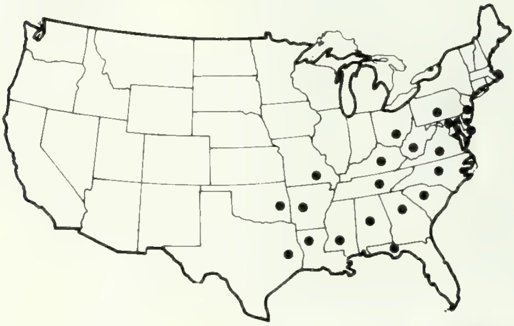
A fast-growing tree up to 100 feet tall and 2 feet in diameter at breast height.

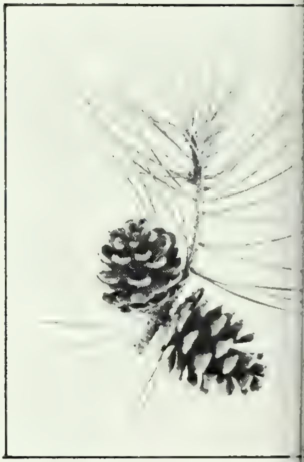
Needles usually two in cluster, sometimes three, 3 to 6 inches long, slender, dark bluish-green.

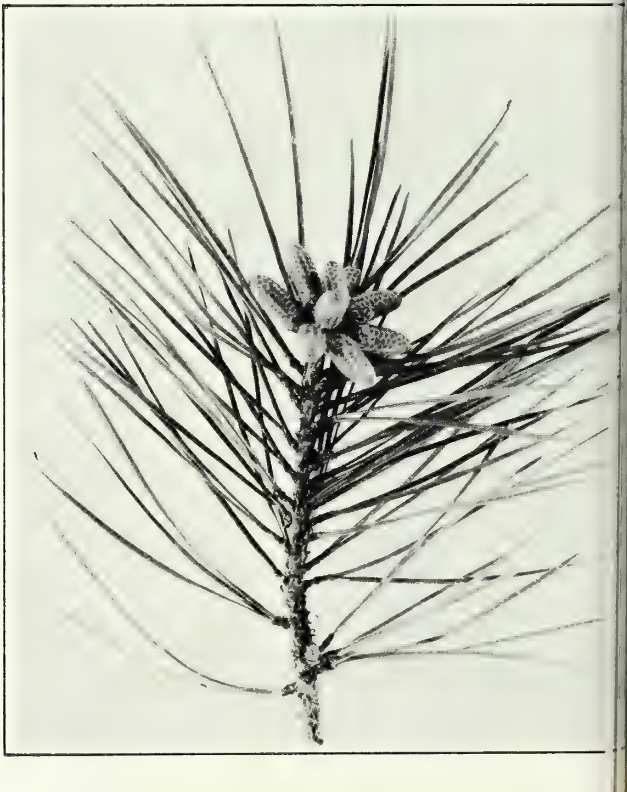
Twigs stiff, stout, brittle, brownish to greenish purple at first, dark red-brown to purple later.

Flowers March to April.

Cone solitary, sessile, or short stalked, 1.50 to 2.50 inches long, persistent on branches, each scale has two triangular seeds about 0.25 inch long, wing about 0.50 inch long. October and November.







Pine cones are a source of food for squirrels. Squirrels eat or cut ine cones when they are still green and in the dough stage in late ummer, then again in late winter when the cone has matured and ropped off. Pine cones are poor quality food but an important source f food during stress periods. Fox squirrels use more cones than gray quirrels.

Seeds from the cones are sought by several kinds of birds and ammals. Wild turkey eagerly pick the loosened seed from fallen cones. he seeds are preferred food for quail and grouse and for many kinds songbirds, particularly the chickadees, crossbills, grosbeaks, jays, tcracker, nuthatches, warblers, and woodpeckers. The seeds, bark, d foliage are eaten by bears, beavers, and rabbits. Squirrels eat the eds and also the catkins.

Foliage of pine seedlings may be grazed by deer, especially the anted seedlings from nursery stock, but it is usually an emergency od and rarely contributes a substantial part of deer diet.

Seven species of pine provide significant food (mainly seeds) and ver for wildlife in the South.

Sand pine [*P. clausa* (Chapm.) Vasey] grows mainly in Florida light, sandy, infertile and slightly acid soils derived from deep posits of marine sand and clay. In parts of north central Florida cala National Forest) the species grows in dense, even-aged pure nds that originated as a direct result of fire. In west Florida sand pine es not need fires to reproduce; thus, it frequently occurs in uneven- ed stands and often invades oak lands. Trees bear cones at about 5 ars of age, and heavy cone crops are usually produced every year. nes remain closed for several years on standing trees until death or a occurs, and seed availability to wildlife is erratic. Cones on harvested es will open when the surface temperature of the soil is high. There about 75 seeds per cone.

Shortleaf pine (*P. echinata* Mill.) grows across the South on a wide riety of soils but does best on fine sandy loams or silt loams that ve no distinct profile and have good internal drainage. Trees begin to ar seed at 5 to 20 years of age, and good to excellent crops occur at ervals of 3 to 6 years. Cones yield about 25 to 35 seeds. Seeds nerally begin to fall in late October and about 90 percent fall by late cember. Shortleaf pine is quite resistant to fires and young shortleaf es sprout readily after a fire or grazing.

Slash pine (*P. elliottii* Engelm. var. *elliottii*) is common in the lower astal Plain on sandy soils that are often underlain with poorly ined hardpans. Outside the flatwoods it usually occurs in narrow

Slash Pine

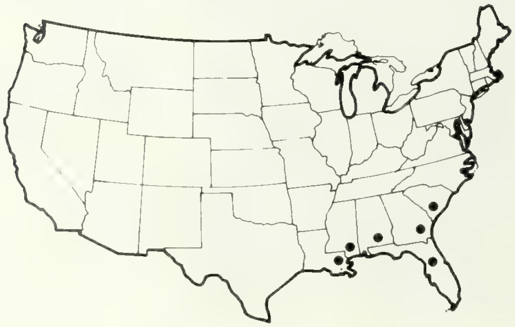
A rapid-growing tree up to 100 feet tall and 3 feet in diameter at breast height.

Needles two to three in clusters, 5 to 10 inches long at end of twig, dark lustrous green.

Twigs stout, orange to brown, buds with silvery-brown scales, terminal bud large, 1 inch long, 0.25 to 0.50 inch thick.

Flowers January to February, before new leaves.

Cone 2 to 6 inches long, 2 to 3.50 inches wide, scales with curved prickle; seeds 0.25 inch long, triangular, wing 0.75 to 1 inch long, thin. September and October.



Longleaf Pine

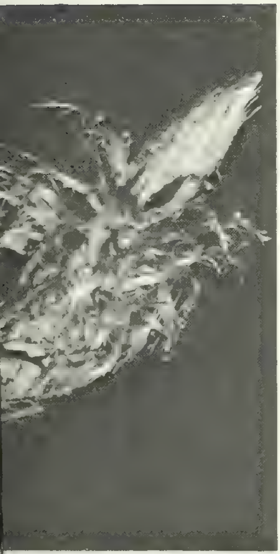
A tree up to 125 feet tall and 4 feet in diameter.

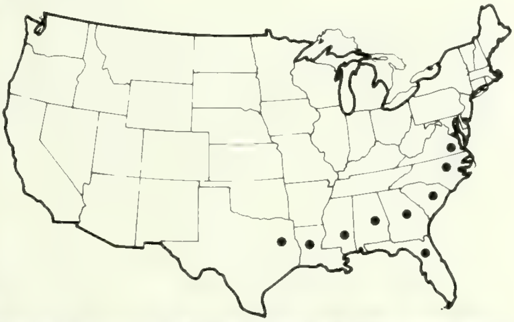
Needles in three's, flexible, slender, 10 to 15 inches long.

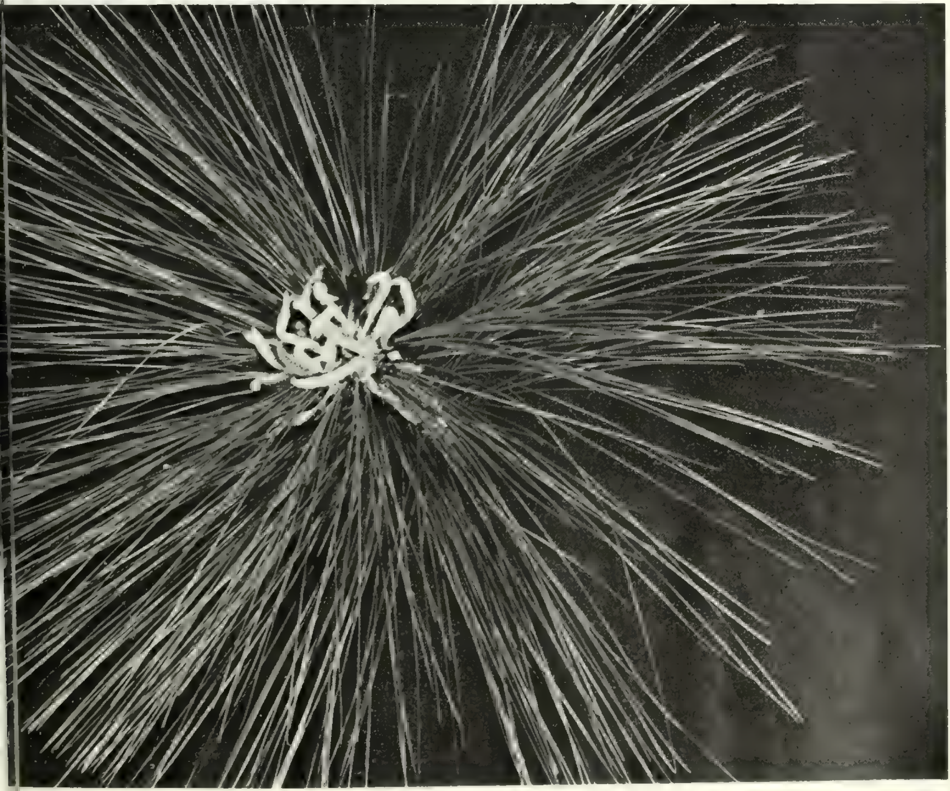
Twigs stout, scaly, orange-brown, buds long, white silvery, scaly.

Flowers February to April.

Cones 6 to 12 inches long, recurved spines. Seeds triangular, ridged, 0.25 to 0.50 inch long, thin wing 1.50 inches long. September and October.







bands along creeks, bays, and minor drainages. Seed production b when trees are 7 to 10 years old or more than 4 inches in diamete breast height. There are about 87 seeds per cone. More than 75 p of the seeds fall during October. The seedlings are easily killed by but after trees are 12 to 15 feet tall winter fire does little damage.

Longleaf pine (*P. palustris* Mill.) grows in sandy soils low in or matter and medium to strongly acid. It is associated with scrub oak (especially turkey and bluejack oaks) on sandy ridges and with slas pine and hardwoods on moister sites. Longleaf begins to bear seed when it is about 6 inches in diameter at breast height. Some open trees will bear cones every year, but good crops are sporadic. Long seeds are the largest of southern pine seeds; mature cones contain 60 seeds. Seeds fall from September to December, mostly within a 2-week period. Longleaf pines are exceptionally resistant to fire ex in the first year after germination and later when 0.50 to 3 feet tall complete protection from fire, other pines and hardwoods invade longleaf sites.

Open longleaf stands are more appropriate than dense stand wildlife because of the more consistent seed production from tree well developed crowns and because of the herbaceous understory When prescribed burned frequently, the stands are especially good habitat for bobwhite quail. Because of their large size, longleaf pin seeds may provide a substantial part of wildlife food on upland ar particularly for fox squirrel and bobwhite quail. Hogs eat the seed the thick succulent root bark of young seedlings and saplings. Go sheep can do considerable damage to young plants.

Eastern white pine (*P. strobus* L.) grows on most all sites with range but best on well drained sandy soils. It begins to bear seeds 5 to 10 years of age. Trees 50 or more years old have yielded wel over 400 cones. The number of good seeds per cone ranges up t and most of the seeds are dispersed in August and September. Resistance to fire is low because of the thin bark on the stem and exposed roots.

Loblolly pine (*P. taeda* L.) grows on a variety of soils from th poorly drained flatwoods of the lower Coastal Plain to the old res soils of the upper Piedmont. It grows best on soils with poor surfa drainage, a deep surface layer, and a firm subsoil. Loblolly pine o grows in pure stands where moisture is plentiful, but it also grows mixtures with shortleaf pine and with many hardwoods, particular sweetgum, oaks, and hickory.

Trees produce their best crops of seed when 35 to 60 years Seed production fluctuates greatly among years, from negligible

Eastern White Pine

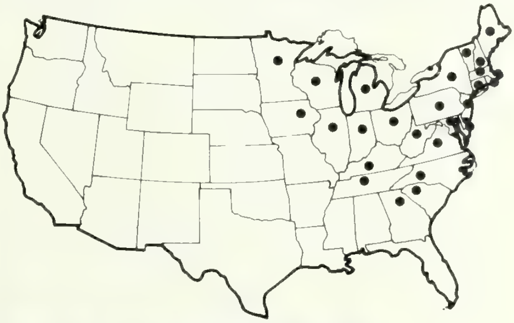
A tree 80 to 100 feet high and 2 to 3.50 feet in diameter at breast height.

Needles 3 to 5 inches long in five's.

Twigs orange-brown, glabrous, buds covered with thin reddish or orange-brown scales.

Flowers May to June.

Cones 4 to 8 inches long, seeds 0.25 inch long, wings 0.75 inch long. August and September.



Loblolly Pine

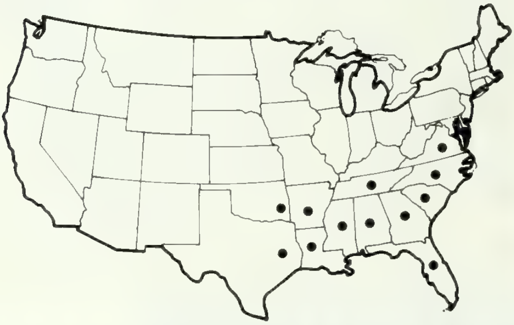
A fast-growing tree 90 to 110 feet tall and 2 to 2.50 feet in diameter at breast height.

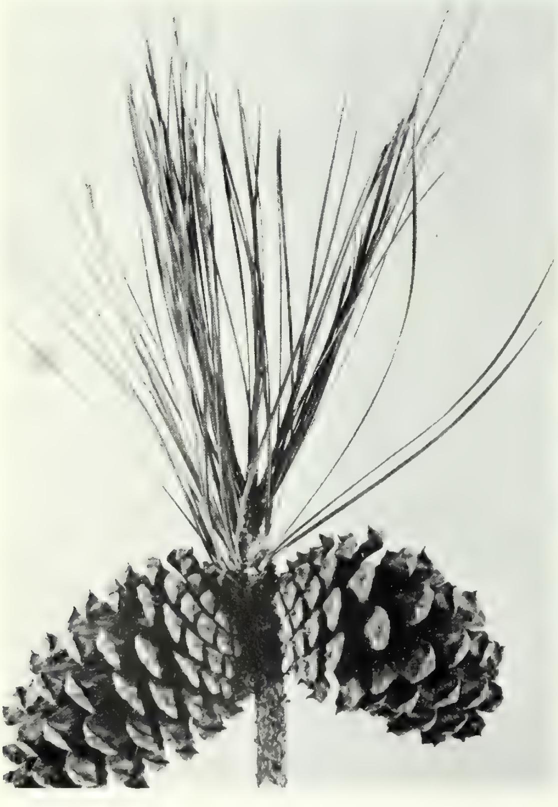
Needles are 6 to 9 inches long in fasicles of three, persistent till third season.

Twigs stout, reddish-brown, scaly, buds covered with reddish-brown scales.

Flowers March to April.

Cones 2 to 6 inches long, two seeds on each scale, 0.50 inch long, thin wing 0.75 inch long. October.





Virginia Pine

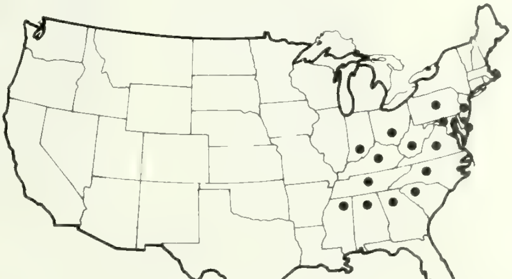
A small to medium tree up to 40 feet high and 12 to 15 inches in diameter at breast height.

Needles 2 inches long in fascicles of two.

Twigs have thin skin.

Flowers March to May.

Cone 1 to 3 inches long, sessile, two seeds in scale, empty cones persistent for 5 to 15 years on tree, seeds 0.25 inch long, wing 0.33 inch long. September to November.



amounts to bounteous crops. Seeds per cone range from 20 to 200 with an average of about 57. Seedfall usually begins the early part o October, and 80 to 90 percent fall by January. Birds and rodents ea many seeds but apparently not enough to hinder regeneration exce poor seed years. Young loblolly pines are very susceptible to fire.

Virginia pine (*P. virginiana* Mill.) grows in the Piedmont, on the foothills of mountains, and on the western edges of the northern Coastal Plain on a wide variety of soils, but best on clay, loam, or sandy loam. It often grows in pure stands, usually as a pioneer transitional type that is eventually replaced by climax hardwoods. Open-grown trees may produce seeds as early as 5 years of age, bu dense stands cone production is delayed up to 50 years. Seeds fall i October and November, however, many cones remain closed for se months or years. Young trees are particularly vulnerable to fire beca of their thin bark. Surface fires may cause considerable damage eve old trees.

Legumes

LEGUMES

Legumes are dry fruits which open tudinally along two sutures and ha or more seeds borne along one su The close relationship of the many members of the legume family is sh their pea-like flowers, pod-like fruit compound leaves.

The seeds of native legumes a eagerly sought by many kinds of w and the cultivated species such as beans and peas are a major sourc food for humans and livestock.

Legumes are characteristicall crude protein and phosphorus.

oneylocust/*Gleditsia triacanthos* L.

owell K. Halls
orest Service, USDA
acogdoches, Texas

his species is found most commonly on the alluvial flood plains of ajor rivers and on soils of limestone origin at elevations below 5,000 et. It develops a strong taproot and a profusely branched root system at penetrates 10 to 20 feet deep.

Honeylocust is intolerant of shade and to survive and mature it ust retain a dominant position in the stand. Its common associates are d maple, blackgum, persimmon, pecan, oaks, elms, ashes, and ckories. On some disturbed soils it is a pioneer species. It matures in out 120 years.

Honeylocust fruit is eaten by rabbits, squirrels, bobwhite quail, and hite-tailed deer. Young plants are preferred forage for rabbits. The eet seed pods are eaten by cattle and by deer, and the flowers are portedly a good source of bee food. The seeds are high in crude otein and phosphorus.

Optimum fruit production occurs when trees are 25 to 75 years old. ood seed crops are produced every year or two, and some seed each ar.

There are several methods recomended for pretreatment of seeds fore planting: soak in water for a short period at 185° to 195°F, arify or soak in concentrated sulphuric acid at 60°to 80°F for 1 to 2 urs.

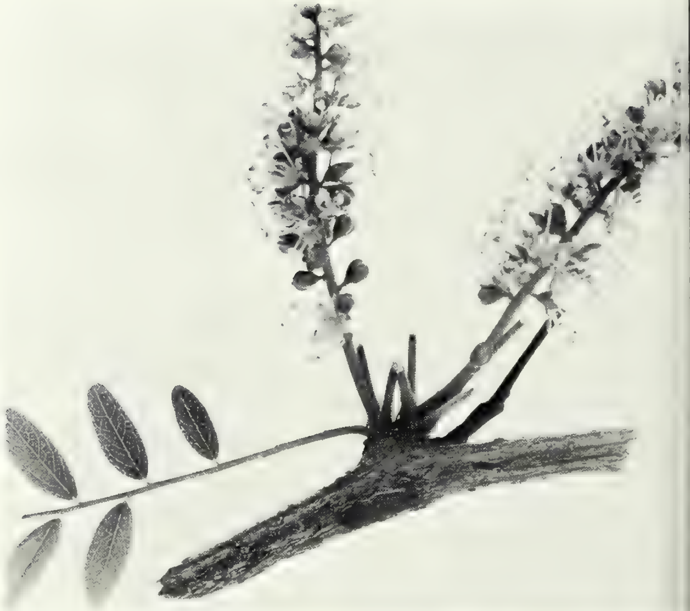
Seed germination is thought to be increased by passage through gestive tracts of birds and mammals.

Honeylocust can be propagated by grafting, by budding, and from rdwood, greenwood, and root cuttings. It sprouts freely.

It is relatively free of insects and disease but is easily damaged by e.

Honeylocust has been in cultivation for many years and is often anted as an ornamental, particularly the thornless kind. The wood is ed for farm implements, fuel, lumber, posts, vehicles, furniture and ilroad crossties.

Other common names: honey-shucks, sweet locust, thorny locust, ree-thorned acacia, common honeylocust.



Honeylocust

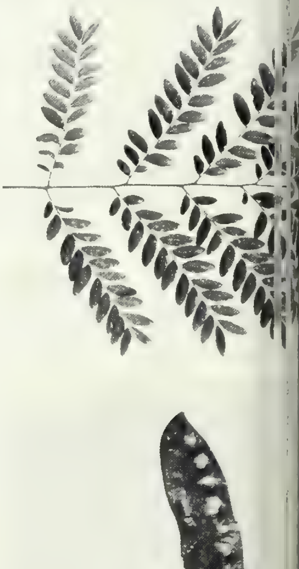
A tree, 70 to 80 feet tall up to 140 feet, 2 to 3 feet in diameter at breast height, maturity in about 120 years. Thorny trunk and branches and a loose open crown.

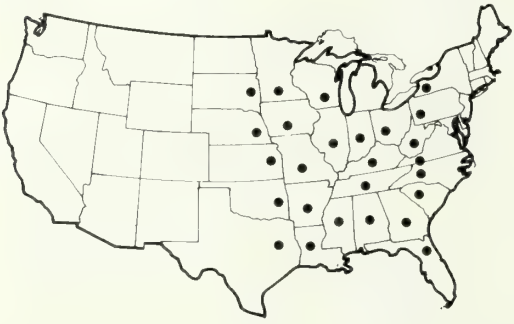
Leaves once or twice pinnate, 5 to 10 inches long, deciduous; 15 to 20 leaflets, 0.75 to 2 inches long.

Twigs zigzag with long, brown, stout spines, usually branched, winter buds minute, three to four together, naked and scaled, terminal bud lacking, thorns absent near top of tree.

Flowers minute, greenish or whitish in narrow clusters at nodes of previous year. May to June.

Fruit a legume, linear, 0.50 to 1.50 feet long, flat, dark brown, slightly curved and twisted, contains many hard, brown seeds. September to October.





lack Locust/*Robinia pseudoacacia* L.

onald D. Strode
orest Service, USDA
ashington, D.C.

ack locust thrives in deep, well-drained, fertile loams. Limestone soils e especially favorable. It does not grow well on very sandy, very acid, wet soil. It is shallow rooted and thus sensitive to soil conditions that pede or produce excessive aeration and drainage. It is highly sceptible to frost damage.

In forest stands it occurs in groups or singly, but on burned-over rest or cleared land it often develops pure stands. Best seed crops cur when trees are between 15 and 40 years of age. Heavy seed crops cur at 1- or 2-year intervals, with light crops in between. Seed pods pen while on the tree during winter and early spring. Few seeds rminate without delay because of the impermeable seed coat, but eds can be softened with sulfuric acid or by soaking in hot water.

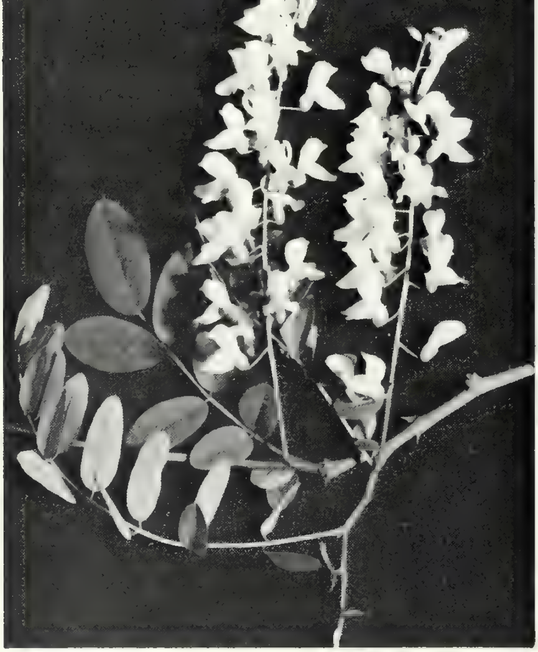
Black locust is very intolerant to shade and is not found in dense ods except as a dominant tree. Where it has room, its rapid growth ables it to compete successfully with more tolerant trees. It usually atures in 20 to 30 years, but trees may live for 40 years or more before ey show signs of deterioration resulting from attacks by fungi and sects. The locust borer is the most serious insect enemy. Iron ficiency and damping off are the most serious seedling diseases.

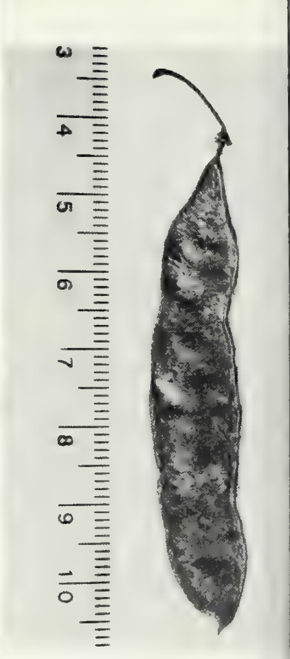
Black locust seeds are consumed to a limited extent by bobwhite ail and other game birds and by squirrels. Foliage is browsed by deer uring the seedling stage. Despite its widespread distribution it does not te high as a wildlife plant.

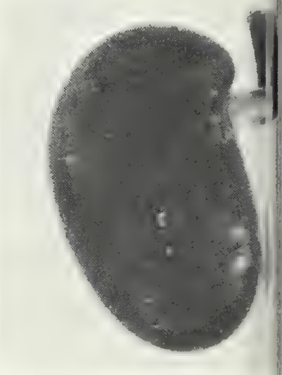
The seeds are very high in crude protein and phosphorus, high in ude fat, and low in calcium.

Black locust heartwood is highly resistant to decay, therefore, it is ed extensively for fence posts and other wood products in contact th the soil. The tree is often used as an ornamental. Being a legume, enriches the soil. Because of its wide-spreading root system it is often anted for erosion control.

Other common names: yellow locust, locust, white locust, green cust, post locust, and false acacia.







Black Locust

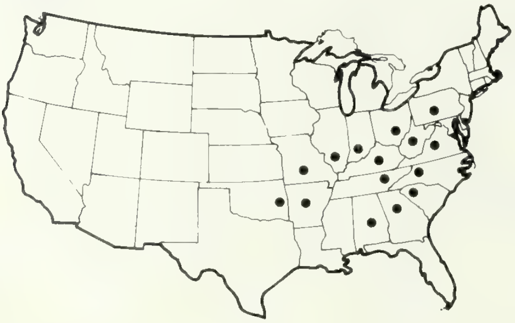
A rapid-growing spiny tree attaining a height of 100 feet, with a trunk diameter of 30 inches.

Leaves pinnately compound, alternate, deciduous, 8 to 14 inches long; 7 to 19 leaflets, 0.50 to 2 inches long; mature leaves bluish-green and glabrous above, paler and glabrous beneath.

Twigs stout, zigzag, brittle, greenish-brown, glabrous, two spines from twig at each leaf, pith homogeneous, no terminal buds, lateral buds naked, leaf scars ovate, three bundle scars.

Flowers loose pendant racemes, 4 to 5 inches long, individual flowers bonnet-shaped, 1 inch long, white, fragrant. May to June.

Fruit a flattened, linear legume, 2 to 5 inches long, 0.50 inch wide, persistent, seeds four to eight, hard flat, kidney-shaped. September to October.



Capsule

CAPSULE

A capsule is a dry dehiscent fruit c posed of more than one carpel. In sweetgum the capsules are fused a base into a round prickly head, ea capsule with one or two winged se

The seeds are high in crude p crude fat, phosphorus, and calciu

***Sweetgum**/Liquidambar styraciflua* L.

Thomas Hooper
Ouachita National Forest
Russellville, Arkansas

Sweetgum is typically a southern species found on moist, moderately ich alluvial soils. However, it is found on a great variety of sites and oils and in association with many species of the various hardwood mixtures as well as certain pine types throughout the southeastern United States. It is rapid-growing, long-lived; and fairly free from insects and disease. As a hardwood it is exceeded in abundance and commercial harvest only by the oak group.

Sweetgum is an early succession plant on disturbed sites, being a prolific seeder that also sprouts readily from roots and stumps after ire, root disruption, and heavy logging. Because of the species' ntolerance to shade, it reproduces only on cleared areas and grows as dominant and codominant trees in the forest. The tree seems to be preferred by squirrels for building leaf nests, and the larger trees are commonly used as dens by squirrels and fur-bearers. Beavers have a iking for this species, which in turn has an unusual tolerance of the animal; a high percentage of beaver-attacked trees survive.

When sweetgum mast begins to mature in July or August, squirrels and chipmunks eat the seeds and continue to take them in quantity on hrough September. Squirrels eagerly seek the buds in spring. In November and December, after the seed balls have opened, bobwhite quail, doves and wood ducks eat seeds that drop to the ground. In Florida, sweetgum seeds were found in 130 of 1,659 quail examined, and several birds had taken as many as 800 seeds. The seeds were up o 8.5 percent of the bobwhite's diet during the month of December. The seeds are an incidental food for wild turkeys.

In good crop years a single tree may produce as much as 30 pounds of fruit (dry weight), and up to 2 pounds of seeds. Bumper rops are produced every 2 or 3 years. The seed is disseminated soon after maturity. Propagation by sprouts is possible but is unsatisfactory for commercial timber production. Propagation is mainly by seeds, and in ommercial plantings seeds should be stratified 30 to 90 days, or water soaked 15 to 20 days before sowing in the spring.

Sweetgum may make a tall, straight stately shade tree in a rather hort time. It has no showy flowers, but the leaves take on some brilliant fall colors. The spiny seed balls detract from its yard value.

Sweetgum

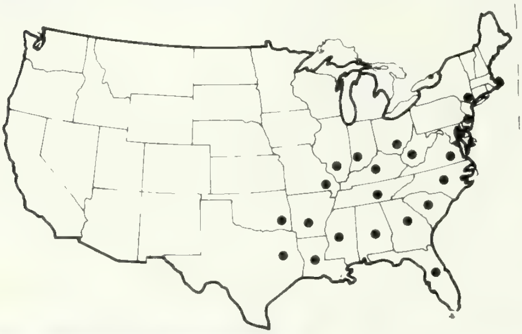
A tree attaining heights up to 150 feet and diameter of up to 48 inches.

Leaves are simple, alternate, deciduous, 3 to 9 inches wide with three to seven lobes, glabrous and glossy above, pubescent along veins beneath, aromatic when bruised.

Twigs rusty-red, glabrous with wide corky wings, or without wings, bark rough, deeply furrowed, brown to grey.

Flowers monoecious, very small, greenish. March to May.

Fruit 1 to 1.50 inches diameter, spinose; seed light brown. September to November, persistent.



The wood is used for flooring, furniture, veneers, general construction, boxes, wooden ware, and several other wood products.

The resinous gum has been used for medicinal purposes, as a perfuming agent in soap, and as an adhesive. It is sometimes chewed by children.

Sweetgum is injured by fire, particularly summer burns. If the sapwood is not killed by fire, a protective layer of gum will form over the wood. However, with repeated fires the fungi and insects may become established and cause extensive damage or death.

Other common names: American sweetgum, redgum, sapgum, whitegum, alligator tree, bilsted.

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Table 1. – *Chemical composition and size of fruits and seeds, and seed-bearing characteristics of plants.*

Plant groups and species	Chemical Composition							Size		Seed bearing characteristics of plants		References
	Part analyzed	Crude protein	Crude fat	Crude fiber	NFE or total carbohydrates	P	Ca	Fruits	Seeds	Minimum age	Interval between large crops	
		Percent of dry weight						Avg number per pound		Years	Years	
Pomes												
Amelanchier canadensis	Fruit	8.1	4.4	12.3	71.5				50,000			20
C. brachyacantha	Fruit	3.9	8.2	29.2	58.3	.13	.13					17
C. crusgalli	Fruit	2.8	3.3	32.8	57.4	.04	.42					20
C. marshallii	Fruit	7.8		47.3		.14	1.56					10
	Fruit	8.8	8.6	34.2		.14	.91					16
Pyrus malus									20,000		2	19
Drupes												
Berchemia scandens	Fruit	6.0	5.7	41.5	46.2	.10	.47	10,000		3	1	9,17
Callicarpa americana	Fruit	5.5			53.6	.12	.26	32,500		2	1-2	9,10
	Fruit	6.9	8.4	30.5		.32	.25					17
Celtis laevigata	Seed	7.2	4.5		34.8[1]	.21	.88	2,200	6,000	15		1,16
C. occidentalis	Fruit	9.5	6.9	8.9	60.0	.30	11.30	2,050	4,300			16,17
	Fruit	8.3	4.4	7.1	52.9	.22	12.40					20
Chionanthus virginicus								630	1,800	5-8		6
Cornus florida	Fruit	5.6	16.7	38.2	37.7	.25	1.50	3,200	4,500	6	1-2	9,16,17
	Seed, de-pulped	5.0	6.2		14.7[1]	.09	1.9					1
	Seed, intact	4.0	20.5		18.3[1]	.13	1.2					2
	Fruit	5.9				12	1.7					10
Gaylussacia dumosa	Fruit	2.5	3.9	23.3	69.5	.06	21		350,000			B
	Seed	4.9	5.1	54.9	34.6	.10	.33					B

Table 1.—*Chemical composition and size of fruits and seeds, and seed-bearing characteristics of plants.*(Continued)

Plant groups and species	Chemical Composition							Size		Seed-bearing characteristics of plants		References
	Part analyzed	Crude protein	Crude fat	Crude fiber	NFE or total carbohydrates	P	Ca	Fruits	Seeds	Minimum age	Interval between large crops	
		Percent of dry weight						Avg number per pound		Years	Years	
Ilex decidua	Fruit	7.4	11.3	35.2	45.6	.11	.28					17
I. glabra	Fruit	5.1	9.0	11.4	72.5	.09	.41		29,000		1	16,B
	Seed	18.1	15.8	28.1	35.5	.30	.81					
I. opaca	Fruit	4.7	7.9	34.0	52.8	.09	.40		28,430	5		16,17
I. vomitoria	Fruit	6.2						6,200	37,800	4	1-2	9,10,16
	Fruit	6.8	7.7	29.9		.09	.16					17
Morus rubra	Seed, intact	11.6	3.8		16.9[1]	.22	.77	3,900	360,000	10	2-3	2,9,16
Myrica cerifera	Fruit	5.3	23.2	30.0	41.1	.04	.28		84,000			16,17
	Fruit	5.6	21.8	42.0	29.0	.04	.26					11
M. pensylvanica	Fruit	7.1	24.8	41.5	24.9	.03	.13		55,000			11,16
Nyssa aquatica								215	456	30	1-2	16
N. sylvatica var. sylvatica	Seed	3.5	10.4		14.5[1]	.18	.06		3,380			1,16
	Fruit	6.4	14.4	35.8	42.7	.35	.31					17
N. sylvatica var. biflora									2,415			16
Prunus pensylvanica									14,200	2		16
P. serotina	Seed, intact	7.8	4.9		20.8[1]	.16	.22		4,240	5	1-5	2,16
	Seed de-pulped	13.7	1.8		15.3[1]	.14	.14					1
	Fruit	13.9	7.0	32.7	43.0	.20	.42					11
P. umbellata	Fruit	7.5	8.6	26.5	56.9	.28	.20					17
[illegible]	Fruit	6.8	6.3	20.9	63.3	.07	.16		4,790			16,20

Rhus copallina var. copallina	Fruit	7.4	26.1	26.8	39.1	.32	.13		57,000			16,17
	Pulp	5.5	10.8	20.7	57.6	.10	.85					11
	Seed	13.4	12.9	29.7	41.8	.37	.14					11
R. glabra	Fruit	6.4	22.4	30.4	40.0	.35	.27	23,000-48,000	49,000	3-4	1	16,17
	Fruit	6.1	11.2	34.9	47.3	.16	.16					20
	Seed, intact	2.4	14.2		16.8[1]	.08	.28					2
R. radicans												
R. typhina								30,00053,300				16
Rubus spp.	Fruit	5.8	4.9	21.5	64.4	.19	.33					11
Sambucus canadensis	Fruit	11.7	16.0	22.4	48.7	.75	.36		232,000		1	16,17
	Fruit	11.1	12.9	17.9	52.6	.36	.13					20
Sassafras albidum	Seed	17.1	46.6		13.6	.23	.06	2,800	5,800	4	2-3	1,9
Viburnum acerifolium								4,800	13,100	2-3	1	16
V. alnifolium								7,580	11,500		3-4	16
V. cassinoides								3,000	27,600		1	16
V. dentatum	Fruit	6.4				.14	.46		20,400	3-4		10,16
V. nudum	Fruit	6.3	12.8	13.3	67.2	.17	.18					17
V. rufidulum	Fruit	4.6	12.7	12.5	69.9	.11	.17	2,300		5		9,17
Berries												
Diospyros virginiana	Pulp	3.3	.9	5.3	87.4	.12	.08		1,200	10	2	11,16
	Seed	4.6	2.0	23.6	63.0	.20	.13					11
	Seed	9.1	2.0		26.6[1]	.20	.03					1
	Fruit	6.1	3.3	10.9	79.4	.11	.10					17
Juniperus virginiana	Seed	5.6	6.8		79.8[1]	.14	.40		43,600	10	2-3	1,16
	Fruit	5.3	14.8	31.5	46.3	.17	.84					17
Lonicera japonica	Fruit	6.2	3.8	9.3	80.0	.15	.49	8,000		3		9,17
	Fruit	10.4	7.8	6.6	69.4	.31	.66					11
Smilax bona nox	Fruit	11.1	7.8	18.6	62.1	.15	.19	5,700		4		9,17

Table 1.—*Chemical composition and size of fruits and seeds, and seed-bearing characteristics of plants.* (Continued)

Plant groups and species	Chemical Composition							Size		Seed-bearing characteristics of plants		References
	Part analyzed	Crude protein	Crude fat	Crude fiber	NFE or total carbohydrates	P	Ca	Fruits	Seeds	Minimum age	Interval between large crops	
		Percent of dry weight						Avg number per pound		Years	Years	
S. glauca	Fruit	9.8	8.2	17.9	63.7	.13	.14					17
	Fruit	10.2	7.5	18.6	60.8	.16	.25					11
S. laurifolia	Fruit	8.9	6.4	17.8	66.5	.23	.09					17
S. rotundifolia	Fruit	7.6	4.1	23.0	64.9	.13	.19	5,900		6		9,11
Vaccinium arboreum	Fruit	3.4										10
	Fruit	3.9	12.2	20.3		.05	.33					17
	Seed, intact	3.0	2.9		33.6[1]	.06	.33					2
Vaccinium stamineum	Fruit	3.8	5.5	11.2	78.0	.05	.05					20
Vitis aestivalis	Fruit	9.1	14.9	22.9	52.3	.36	.38					17
V. cinerea	Fruit	6.4	7.2	19.8	66.0	.17	.38					17
V. rotundifolia	Fruit	4.8						635		4		9,10
	Fruit	6.6	9.0	18.3		.21	.43					17
V. vulpina	Fruit	5.4	0.9	13.4	77.6	.15	.06		14,500			19,20
	Fruit	9.8	9.5	22.2	54.3	.26	.52					11
Nuts												
Carpinus caroliniana	Seeds	11.6	9.7	51.8	26.5	.22	.12		30,000	15	3-5	16,17
Carya aquatica	Kernel	10.2	32.0	3.2	54.2	.20	.15		164	20	1-2	16,17
C. cordiformis	Kernel	7.5	48.3	2.4	41.3	.24	.16		156	30	3-5	16,17
	Seed, husked	3.3	30.8		17.1[1]	.12	.46					2
C. glabra									200	30	1-2	16
C. ovata	Kernel	13.3	74.4	1.5	8.8	.37			100	40	1-3	16,20

C. tomentosa	Kernel	11.9	82.6	2.9	2.0	.35	.14	36	25	2-3	16,17
	Seed, husked	3.7	20.0		12.7[1]	.08	.22				2
Fagus grandifolia	Seed	7.8	10.6		6.5[1]	.26	1.18	1,600	40	2-3	2,16
Juglans cinerea								30	20	2-3	16
J. nigra	Kernel	29.3	60.2	1.0	6.7	.59	tr	40	12	2-3	16,20
	Kernel	28.2	64.3	1.9	4.7	.60	.09				17
	Seed, husked	5.1	10.5		14.4[1]	.20	.07				1
	Kernel	23.1	60.4		3.8[1]						1
Ostrya virginiana	Seed	15.3	19.8	46.4	17.0	.28	1.09	30,000			16,17
Quercus alba	Acorn	6.3	6.3	2.5	82.3	.16	tr	120	20	4-10	16,20
	Acorn	4.6	2.9		46.6[1]	.08	.22				1
	Acorn	4.1	1.2	19.9	74.4	.08	.27				17
Q. chapmanii	Acorn	4.5	4.5	17.0		.10	.28				C
Q. falcata var. falcata	Acorn	6.5	15.8	18.1	59.2	.10	.21	540	25	1-2	16,17
	Acorn	4.2	15.6	20.6	57.7	.08	.43				11
	Acorn	5.1	17.0		23.0[1]	.08	.32				2
Q. ilicifolia	Acorn	10.3	20.0	3.0	64.6	.19	tr	700			16,20
	Acorn	6.1	19.4	18.3	54.6	.10	.19				11
Q. incana	Acorn	6.2	20.0	15.9	57.5	.15	.18	218			17
Q. laurifolia	Acorn	5.0	26.8	3.4	62.3	.10	.09	560	15	1	16,A
Q. marilandica	Acorn	7.0	16.2	19.0	57.4	.11	.26	210			17
	Acorn	6.3	10.7	20.9	60.1	.09	.37				11
Q. michauxii	Acorn	4.1	3.3		56.1[1]	.12	.08	85	20	3-5	2,16
Q. minima	Acorn	6.6	7.2	13.5	72.5	.06	.05		4		9,17
Q. nigra	Acorn	3.8	20.3		25.8[1]	.06	.32	395	20	1-2	1,16
	Acorn	5.3	20.5	16.7	57.1	.08	.28				17
Q. nuttallii	Acorn	4.4	5.2	26.4	63.6	.08	.20	95	5	3-4	16,17
	Acorn	3.8	15.0	13.2	66.6	.05	.17				11
	Acorn	4.5	13.2		46.2[1]	.09	.04				2

Table 1.—*Chemical composition and size of fruits and seeds, and seed-bearing characteristics of plants.*(Continued)

Plant groups and species	Chemical Composition							Size		Seed-bearing characteristics of plants		References
	Part analyzed	Crude protein	Crude fat	Crude fiber	NFE or total carbohydrates	P	Ca	Fruits	Seeds	Minimum age	Interval between large crops	
		Percent of dry weight						Avg number per pound		Years	Years	
Q. phellos	Acorn	5.9	19.6		31.2[1]	.08	.18		462	20	1	1,16
	Acorn	5.1	21.1	17.2	56.1	.09	.27					17
Q. prinus	Acorn	4.6	1.0	29.4	64.6	.11	.16		100	20	2-3	16,17
	Acorn	6.9	5.1	2.6	83.2	.15	tr					20
	Acorn	6.4	3.3	15.2	72.9	.12	.14					11
Q. pumila	Acorn								360	4		9
Q. rubra	Acorn								125	25	3-5	16
Q. stellata	Acorn	5.2	5.7	19.5	66.7	.11	.40		380	25	2-3	11,16
	Acorn	3.8	5.2		37.9[1]	.08	.25					1
	Acorn	8.3	5.1	15.8		.10	.15					17
Q. virginiana var. virginiana	Acorn	4.4	8.2		46.4[1]	.06	.06		352		1	1,16
	Acorn	5.9	6.9	15.1	71.8	.09	.13					17
Cone and Conelike												
Magnolia grandiflora	Seed, intact	10.8	41.2		12.4[1]	.28	.17		6,450	10	1	2,16
M. virginiana	Seed	9.3	38.5	28.3	23.2	.23	.33		7,530	6		9,16,17
Pinus clausa									75,000	5	1-2	16
P. echinata	Seed	26.7	17.6	32.7	22.2	.65	.05		46,300	5-20	3-10	16,17
	Seed	28.6	22.1	32.9	9.9	.76	.08					11
P. elliottii var. elliottii									13,500	7-10	2-3	16
P. palustris	Seed	26.7	19.3	37.1	13.5	.68	.04		4,900	20	5-7	16,17

	Seed	15.9	6.7	56.4	17.0	.35	.04				11
P. virginiana								55,400	5	1-3	16
Legumes											
Gleditsia triacanthos	Seed	17.5	2.6		16.9[1]	.31	.10	2,800	10	1-2	1,16
	Seed	26.5	2.4	13.5	56.5	.69	.28				17
Robinia pseudoacacia	Seed	38.7	9.0		12.3[1]	.68	.05	24,000	6	1-2	1,16
	Seed	44.8	8.6	19.3	26.5	.63	.13				17
Capsule											
Liquidambar styraciflua	Seed	25.3	26.2		11.6[1]	.69	1.51	82,000	20-30	2-3	1,16
	Seed	26.7	23.7	20.2	27.9	.55	.85				17

[1] Total carbohydrates.

A Beckwith (unpublished)

B Knox (unpublished)

C Spratt (unpublished)

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escribes and provides illustrations of 106 woody plant species that oduce fruit useful to wildlife in southern forests. It also includes formation about plant growth requirements, management, and nutrional quality. Trees, shrubs, and vines that produce fleshy fruits or nuts e emphasized.

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Summary

Yellow-poplar can be established on a wide variety of sites with bare-rooted seedlings and standard planting techniques. Many past plantings have performed poorly because substandard seedlings have been planted on unsuitable sites and competing vegetation has not been adequately controlled. Research over the past two decades, however, provides workable guides for site selection, planting practices, and competition control. Enough is now known that the forester can avoid or overcome the most common causes of failure.

This paper mentions the use of herbicides. If herbicides are handled, applied, or disposed of improperly, they may be injurious to humans, domestic animals, desirable plants, and pollinating insects, fish, or other wildlife, and may contaminate water supplies. Use herbicides only when needed and handle them with care. Follow the directions and heed all precautions on the container label.

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1977

Planting Yellow-Poplar — Where We Stand Today

T. E. RUSSELL

Large volumes of yellow-poplar (*Liriodendron tulipifera* L.) are used for furniture, plywood, corestock, millwork, siding, and other light construction lumber. Though seldom managed exclusively for roundwood, yellow-poplar is used for pulping and for products manufactured from chips or flakes. Rapid growth and excellent form make this species an outstanding candidate for planting.

Yet despite its favorable potential for growth and the desirable properties of the wood, relatively few yellow-poplar plantations are being established. Most foresters and landowners are probably discouraged by the preponderance of failures in past efforts. For example, the North Carolina Division of Forestry sold 7 million yellow-poplar seedlings between 1947 and 1966, but by 1970, only 53 percent of the planting sites could be located and of these only 7 percent could be considered successful in terms of adequacy of stocking and growth (Boyette 1970). Comparable data are not available for other Southern States, but general observations indicate that the success rate in Tennessee and Alabama is about the same.

In view of this record of failures it is not surprising that so few foresters think of yellow-poplar as a plantable species. The problem may, however, reflect a lack of knowledge of recent developments in yellow-poplar research. The purpose of this paper is to review available information and to consider whether there is an adequate technical basis for planting yellow-poplar.

Technical Considerations

Yellow-poplar has been studied more than any other upland hardwood, and more is known about planting this species than is commonly realized. The key requirements for planting yellow-poplar are:

(1) Selection of suitable sites.
(2) Use of the best planting technology, including high-quality seedlings, careful stock handling, and choice of appropriate seasons and methods of planting.
(3) Adequate control of competing vegetation.

Site Selection

Improper site selection has probably caused more disappointing plantation performance than all other mistakes combined. The extremely high rate of failure in the North Carolina survey resulted mainly from planting on unsuitable sites (Boyette 1970).

Broad recommendations concerning planting sites can be made, but they should be modified to fit the local situation. Much information about soil and site requirements for yellow-poplar has been compiled in summary publications which are useful guides to selecting planting sites (Carmean 1970, Olson 1969). Although this information was derived largely from natural stands, many of the relations between topographic features or soil properties and site quality apply for plantations as well (Limstrom 1963, Smalley 1969, Tryon and others 1960).

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The definition of a suitable site for planting yellow-poplar depends largely on the rate of growth that the forester or land manager considers acceptable. We consider areas with a site index of 85 or more to be satisfactory; anything less is unsatisfactory. At site index 85, early growth of planted yellow-poplars will average about 2 feet per year. The best trees, those that will eventually dominate the stand, will average about 3 feet per year.

Where no yellow-poplar site-index trees are available, site index can be determined for other tree species and related to site for yellow-poplar by comparative site-index data (Doolittle 1958, Olson and Della-Bianca 1959). Where there are no site-index trees site evaluation involves more risk, but a judicious consideration of soil and topographic requirements should enable the planter to avoid doubtful situations and to put yellow-poplar on sites capable of yielding satisfactory growth.

Soils and topography. — Excessively drained soils and very wet soils are not good sites (Olson 1969). Some moderately to poorly drained soils in the Northeast are very productive, possibly because favorable amounts of moisture during much of the growing season compensate for poor aeration in the subsoil during part of the year.

Other important soil factors include depth of the A horizon (especially the Al), surface or subsoil texture, and total soil depth. Site quality generally increases with increasing soil depth and especially with increasing thickness of the A horizons (Carmean 1970). Ordinarily, yellow-poplar should not be planted on any soil with less than 24 inches of rooting depth over bedrock, fragipan, or other restrictive horizon.

Although few soil-site studies have found strong correlations between soil nutrients and site quality, yellow-poplar apparently grows poorly on nitrogen deficient soils and attains best growth only with an ample supply of nitrogen (Olson 1969). Some soils have low levels of calcium and high levels of soluble aluminum in the subsoil that may inhibit root development and thus lower site quality for yellow-poplar (Loftus 1971).

Topographic features that most consistently correlate with yellow-poplar site index in a number of studies are slope position and aspect, (Carmean 1970). In mountainous or hilly terrain, best sites are coves or deep hollows. North and east aspects are better sites than south and west aspects, lower slopes are usually better than upper slopes, and gently, concave land forms are more likely to be good sites than steep, convex slopes.

Yellow-poplar should not be planted on narrow, dry ridges. Broad ridges may be fair sites, provided that rooting depth and soil texture is favorable. For example, yellow-poplar planted on broad ridges of the Cumberland Plateau has grown well on soils with textures from fine sandy loams to clay loams, where rooting depth was adequate and the Al horizon was 2 or more inches thick. On steep slopes, subsurface flow may improve moisture conditions downslope enough to provide acceptable growth even where soils are less than 24 inches deep.

Planting on old fields. — Though some agricultural lands can grow hardwoods, abandoned fields or pastures are usually less favorable for yellow-poplar than recently forested areas occupying similar soils. Moreover, site quality on old fields in the uplands often varies greatly within short distances (Gilmore and others 1968), complicating the task of assessing site suitability for yellow-poplar. Adverse conditions commonly found on old fields include severe erosion, soil compaction, a depleted nutrient capital, and a heavy sod or weed growth. Loss of the A horizon, degradation of soil structure, and lack of appropriate soil micro-organisms are major reasons for poor performance of planted yellow-poplar on many old fields in the Central States (Clark 1964, Clark and Losche 1969). Where old fields have been invaded by a brushy cover of trees and shrubs, soil conditions may have improved enough to support yellow-poplar; an initial rotation of pines or nitrogen-fixing tree species can also improve soil conditions on old fields (Carmean and others 1976).

Planting Technology

Assuming that the site is capable of growing yellow-poplar at an acceptable rate, close attention to seedling quality, stock handling, and the actual planting operation is essential.

Seedling selection. — Seedling size indicates physiological vigor, and we have generally accepted that large hardwoods seedlings initially perform better than small seedlings (McElwee 1970, Rodenbach and Olson 1960). Moreover, the beneficial effects of planting high-quality seedlings may persist for many years (Funk and others 1974). Most yellow-poplar planting is done with 1-0, bare-rooted stock. Based on published guides for the Central States, seedlings with diameters of about 10/32 inch at the ground line are preferred (Limstrom 1963). The current trend in the South is to plant even larger hardwood seedlings; a root collar diameter of 12/32 inch is often considered the minimum acceptable size (McElwee 1970, Nugent 1971). Four-year-old yellow-poplar seedlings have been recommended for planting sites in West Virginia that are dominated by tall-growing herbaceous weeds

(Carvell 1966a). Seedlings within the 8/32 to 12/32 range have performed satisfactorily in many trials on a wide variety of sites in central Tennessee and northern Alabama (Russell and others 1970). Seedlings of this size not only provide satisfactory performance but also are not too unwieldy for bar-slit or machine planting.

Quality of planting stock depends on the genetic make-up of the seedlings as well as on their morphological grade. Current work on selection and breeding is in progress and offers the possibility of improved planting stock, but until improved stock becomes available, an important genetic consideration is seed origin.

In North Carolina, seedlings from local sources survived better than those from non-local sources although there were no significant differences in fifth-year heights (Sluder 1960). Moving yellow-poplars northward from their origin into areas of much longer day length may increase juvenile growth (Limstrom and Finn 1956) but increases risk of severe frost damage (Funk 1958). In a study of four mid-South seed sources, seed source had no important effects on sixth-year heights in outplantings at Vicksburg, Mississippi; Birmingham, Alabama; and at two locations near Sewanee, Tennessee. Trees of southern origins consistently leafed-out before those from northern sources in all four outplantings (Farmer and others 1967). Nor in 15 years have there been any serious climatic injuries to yellow-poplars from south Mississippi that were moved 4 degrees north and outplanted 1700 feet higher on Tennessee's Cumberland Plateau.

Yellow-poplars grown from seed collected in North Carolina's Appalachian Mountains have either survived poorly when planted in the Coastal Plain or have grown more slowly than seedlings from Coastal Plain sources (Kellison 1968, Lotti 1955). Apparently, there is a yellow-poplar ecotype adapted to the highly organic and poorly-drained soils of the Coastal Plain. In Tennessee, seedlings from high elevations have not grown as well as those from lower elevations even when planted at relatively high elevations (Thor 1976).

Wherever research or experience indicates the superiority of a specific non-local source that source should be used. When such information is lacking you should obtain seed from as near the planting site as possible. Local sources will not always grow best, but they will be well enough adapted to the environment to minimize risks of catastrophic losses from adverse weather.

Seedling handling and planting — Even when the nurseryman provides seedlings capable of surviving and growing well, proper stock handling and planting are necessary for success. Yellow-poplar seedlings apparently require more care than hardier species such as pines. Allowing yellow-poplar seedlings to dry out, heat, or freeze during shipment, storage, or planting may seriously reduce early survival.

Seedlings can be kept in bales for a few weeks in a cool, shaded place. They can be heeled-in safely for a longer time but should be planted before new leaves unfold. Refrigeration at about 36° F is best for long-term storage (Limstrom 1963). At Sewanee, Tennessee, cold storage has kept seedlings dormant and in good condition for almost six months. Cold storage, however, does not eliminate the need for reasonable care; bales should be turned about every 2 or 3 weeks to prevent heating and watered before the packing medium feels dry to the touch.

Optimum planting dates vary with local climate. In regions with severe winters, seedlings planted in the fall or winter may be injured by frost heaving, particularly on heavy soils or where intensive mechanical site preparation has removed all cover. Thus spring planting is usually preferable. In central Tennessee and northern Alabama, we usually plant between mid-February and April but have planted as early as January or as late as mid-May. Seasonal weather fluctuations have had no effect on planting success within this range of dates (Russell and others 1970).

The choice of planting methods depends mainly on the size of the planting area, its soils, topography, and the density of residual trees, brush, and logging debris. Although relatively little yellow-poplar has been planted with machines, machine planting has worked well on suitable terrain. Most yellow-poplar planting has been done by hand, using the bar-slit technique. The main requirement for hand planting is that the tool selected should be adapted to the soils of the planting site and make a hole large enough to accomodate the yellow-poplar root system.

Roots and shoots are often pruned in the nursery to reduce costs of packing and shipping. Root pruning tends to increase branching or root mass (Sluder 1964, Thor 1965) and may improve survival and early growth (Limstrom and others 1955, Sterling and Lane 1975). Roots should not be pruned without also clipping tops as this may reduce first-year growth. Seedlings that have not been pruned at the nursery can be pruned in the field for ease in handling and planting. Overlong roots should be cut back to about 10 inches; tops can be clipped to a length of 12 to 18 inches.

Choice of spacing depends on such factors as length of rotation, product size objective, anticipated survival, and whether or not plantations can be thinned profitably. There is little specific information about the effects of spacing on growth of planted yellow-poplar. Average heights of a 22-year-old plantation in Michigan were not affected by spacings ranging from 8 x 8 to 14 x 14 feet. Although mean diameters for the entire stand increased progressively with wider spacings, diameters of the largest 100 trees per acre were about the same at all spacings (Rudolph and others 1965). One general planting guide recommends giving yellow-poplar seedlings 60 to 90 square feet of growing space (McElwee 1970). Most of Sewanee's studies have been planted at spacings of 6 x 8 or 7 x 7 feet (about 900 trees per acre). In view of the excellent survival achieved, narrower spacing probably cannot be justified.

Control of Competing Vegetation

A crucial question facing the forest manager concerns the amount of competition control needed for satisfactory establishment and growth of yellow-poplar. Seedlings grow so fast that they can outstrip much low-growing vegetation on cutover sites, but they are also intolerant and will not persist for long in the understory or grow well on clearcut areas if overtopped by faster growing sprouts (Olson 1969). Lack of overstory removal and cleanings was a major reason for the poor performance of yellow-poplar in North Carolina even when planted on suitable sites (Boyette 1970).

Some general recommendations for planting hardwoods indicate that complete site clearing and one or more years of rigorous weed control are essential for successful hardwood establishment (Belanger and Saucier 1975, Kellison 1971, Nugent 1971, Smith 1973). But studies of yellow-poplar plantations indicate that satisfactory performance can be obtained on many sites without resorting to such intensive practices.

Chemical Control. — Research in central Tennessee and northern Alabama demonstrates that yellow-poplar can perform reasonably well on cutover sites of intermediate quality without complete elimination of competing vegetation (Russell and others 1970). Competition control methods commonly used when planting pines in these regions have also worked well with yellow-poplar. Where understories were sparse, with few trees under 2 inches dbh, deadening hardwoods by girdling, frilling, or injecting with a herbicide was all that was needed to insure satisfactory survival and growth of planted poplar. Similar techniques for underplanting and release have also worked in West Virginia (Carvell 1966b).

A recent study on the Cumberland Plateau illustrates how well yellow-poplar can grow on average sites with minimum site preparation and no follow-up cleaning (McGee 1977). Yellow-poplars were planted at a spacing of 7 x 7 feet. Before treatment the stand consisted of several species of oaks, hickories, red maple, sourwood and an occasional yellow-poplar. Basal area in trees over 4 inches dbh was 40 square feet per acre. The midstory had 650 hardwoods per acre smaller than 4 inches dbh but larger than 1 inch dbh. Understory stems smaller than 1 inch dbh varied from 5000 to 10,000 per acre over the study area. Where only the unwanted hardwoods over 2 inches dbh were injected, planted yellow-poplars averaged 25 feet in height and 2.3 inches in diameter after 10 years. Controlling all hardwoods boosted average height to 31 feet and average diameter to 3.2 inches. Survival after 10 years was 76 percent for both treatments. Even though complete control of competing hardwoods improved growth, the much cheaper treatment has provided 122 trees per acre 4 inches dbh and larger — an adequate number of crop trees for management.

On high-quality sites the minimum treatments described above will not provide sufficient release for adequate performance of yellow-poplar. Here a fairly complete control of small understory hardwoods will be needed. Foliar sprays before planting provide the only practical way to control dense thickets of small hardwoods and brush where mechanical clearing is not feasible.

Plantations should be checked annually for up to 5 years to determine whether additional release is necessary. On intermediate sites where stems 4.5 feet high and larger are killed before seedlings are planted, follow-up cleanings should seldom be needed. On high-quality sites, even preplanting foliar sprays seldom completely eliminate small hardwoods, and hand cleaning may often be needed. Cleaning can be done by cutting or basally spraying competing stems (Limstrom 1963). Area-wide foliar sprays cannot be used after planting because yellow-poplar is too sensitive to herbicides. In natural stands, total release of sapling yellow-poplars from competition significantly reduced height growth (Allen and Marquis 1970). Thus, cleaning should be limited to freeing only overtopped or severely crowded trees, and complete removal of al unwanted hardwoods should not be attempted.

Mechanical Control. — Intensive mechanical site preparation can be used in areas of gentle topography and nonerosive soils and essentially eliminates problems from unwanted hardwoods. However, on any site good enough to grow yellow-poplar, complete site clearing usually triggers a succession of dense herbaceous vegetation.

Although we have no direct comparisons, early growth on mechanically prepared Cumberland Plateau sites without weed control or fertilization has usually been somewhat poorer than growth on the same soils where unwanted hardwoods were deadened with chemicals. This suggests that drastic disturbance may lower the productivity of some upland sites for yellow-poplar, possibly because soil properties are altered or because complete clearing promotes a heavy invasion of herbaceous weeds and grasses.

Even though yellow-poplar can be planted on mechanically cleared sites without postplanting weed control, these treatments may greatly increase early growth. On well-drained alluvial sites in Georgia that were clearcut, sheared, and disked, control of invading herbaceous weeds markedly increased early growth of planted yellow-poplar (Fitzgerald and Selden 1975). Both survival and height growth in plantations in Iowa were improved by eliminating a dense grass sod (Erdman 1967).

Yellow-poplar seems to respond increasingly from moderate release up to complete elimination of herbaceous vegetation on sites where grasses and broadleaved weeds are a problem. Such intensive culture may not be practical now but may have a place in the future management of yellow-poplar wherever the objective is to achieve the full potential of the species.

Weed control on fertilized plantations. — Yellow-poplar reacts positively to nutrient additions, especially nitrogen (Broadfoot and Ike 1968, Ike 1972), and favorable responses have been obtained in several old-field plantations (Auchmoody and Wendel 1973, Blackmon and Broadfoot 1970, Farmer and others 1970, Finn and White 1966). Fertilizers increase growth and shorten the period to crown closure but also greatly stimulate weeds and increase the need for weeding.

Results from two recent unpublished studies at Sewanee show how postplanting weed control and fertilization can influence growth of yellow-poplar on Cumberland Plateau sites of average quality.[1] Both areas were prepared by shearing, windrowing, and disking. For both studies, fertilizers were applied at the start of the second growing season after planting at a rate of 150 pounds of nitrogen and 100 pounds of phosphorus per acre. Weed control treatments were started in the second growing season as soon as weeds began vigorous growth and were repeated whenever regrowth averaged about 18 inches in height. In the first trial, fifth-year heights averaged 11.1 feet where weeds were controlled for 2 years by mowing, 12.1 feet on broadcast fertilized plots, and 7.9 feet on plots that were neither mowed nor fertilized. Combining weed control with fertilization boosted fifth-year heights to 14.3 feet. In the second study, where fertilizers were applied to 4-foot-wide strips that were then cultivated yellow-poplars averaged 7.5 feet 2 years after planting (fig. 1). Heights were 5.9 feet on strips that were only cultivated and 5.5 feet on strips that were only fertilized. Second-year heights of seedlings that received no postplanting treatments averaged 3.2 feet.

Prospective Growth

Reluctance to accept planting as a viable way to regenerate yellow-poplar results partly from land managers' lack of confidence in being able to obtain adequate growth. Plantations growing on suitable sites are scarce, especially those that are old enough that we can forecast their ultimate growth. However, there is enough experience from a number of regions to show that satisfactory growth is possible and under appropriate conditions is not difficult to obtain.

Possibly the best recorded growth of planted yellow-poplar was on a bottomland old field in the Piedmont of Georgia where dominants attained an average height of 70 feet in 17 years (Nelson and Jackson 1956). In a

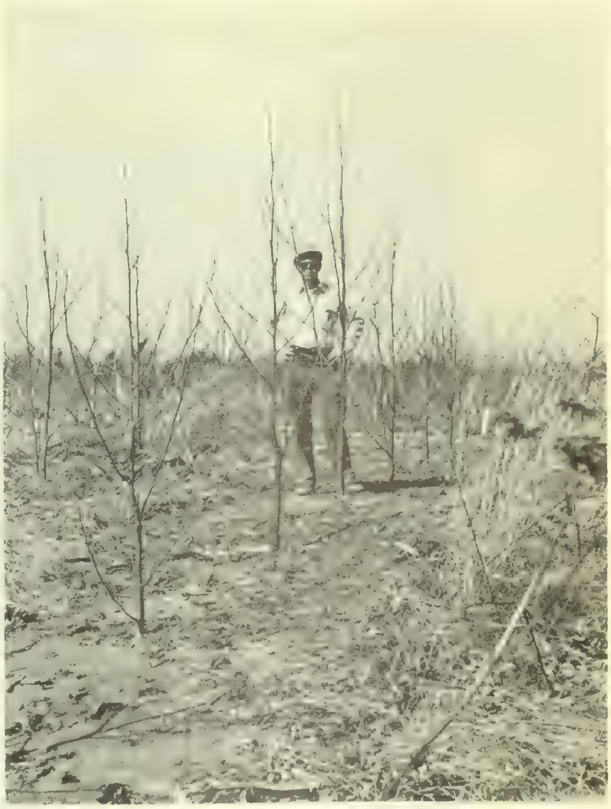

Figure 1 — A 2-year-old plantation on a sheared and disked site on the Cumberland Plateau. Trees were fertilized 1 year after planting and were cultivated during the second growing season.

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[1] These continuing studies are recorded in the files of the Sewanee Silviculture Laboratory as studies 1105-1.22 and 1105-1.32.

Tennessee provenance trial with fertilization and weed control, the best seed source averaged 48 feet in height and 6 inches dbh fifteen years after planting on good agricultural soil (Thor 1976).

Two additional plantations in Tennessee illustrate the performance of planted yellow-poplar on cutover forested sites of widely differing quality.[2] One, located on a broad ridge on top of the Cumberland Plateau, has a 50-year yellow-poplar site index estimated to be 85. The second plantation is on a steep northwest facing slope of the Plateau escarpment and, with site index of about 110, typifies the best hardwood sites in the area. For both plantations site preparation consisted of applying a herbicide in frills to residual hardwoods over two inches in diameter and as a basal spray to smaller stems in the moderately dense understory. Seedlings were planted at a spacing of 5 x 5 feet, and both plantations were thinned after their eighth year to maintain diameter growth. After thinning, stands on the Plateau ridge and Plateau slope had 505 and 440 trees per acre, respectively.

Fifteen years after planting, yellow-poplars on the Plateau ridge averaged 34 feet in height and 3.7 inches dbh (fig. 2). The best 20 percent of the stand averaged 41 feet in height and 5.0 inches in diameter. On the Plateau slope, average height of the total stand was 51 feet and dbh was 5.4 inches (fig. 3). Trees in the top 20 percent averaged 59 feet and 6.8 inches.

Diameter distributions in these 15-year-old plantations provide additional insight into the prospective performance of yellow-poplar planted on cutover forested lands:

Planting Site	DBH — Inches								
	<4	4	5	6	7	8	9	>9	Total
	Number of stems per acre								
Plateau ridge	239	151	76	29	9	—	—	—	504
Plateau slope	67	91	109	84	49	27	7	6	440

Conclusions

Recent research and experience indicates that planting yellow-poplar is technically and biologically feasible. Expanded planting programs should be considered first on sites in the site-index range of 85 to 100. On these intermediate sites, yellow-poplar grows fairly well, and competition is less formidable than on higher quality sites. Planting should be particularly attractive where repeated high-grading, fires, or grazing have eliminated the yellow-poplar seed source. This situation occurs

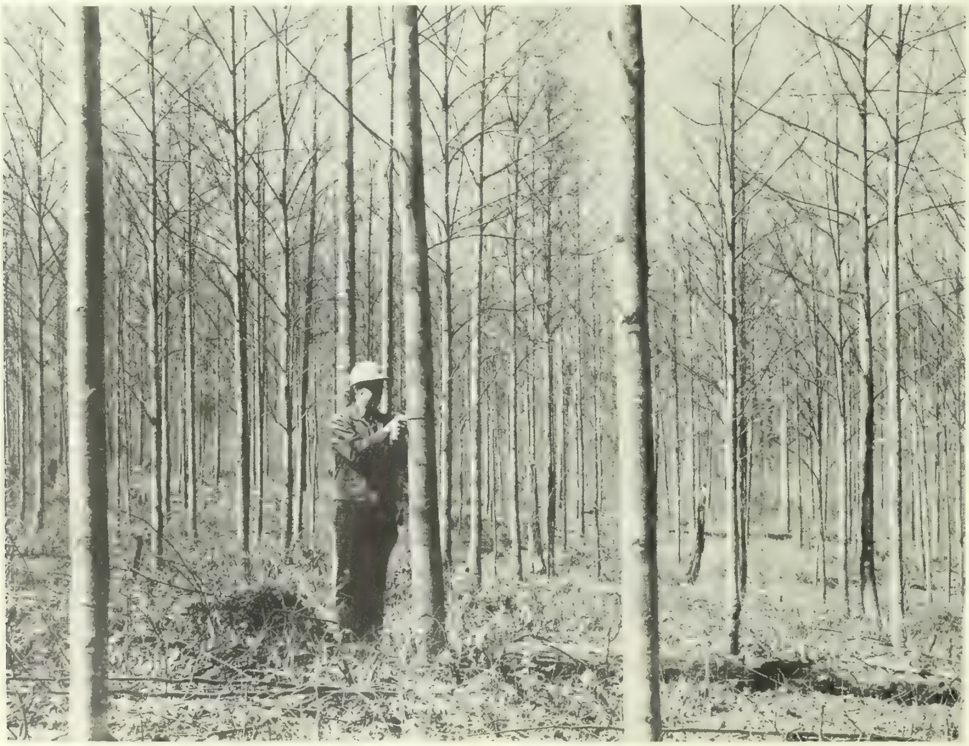

Figure 2.—A 15-year-old plantation on a Cumberland Plateau ridge with site index 85 for yellow-poplar.

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[2] Eight-year results for these plantings were reported in Research Paper SO-63 as Plateau-ridge Plantation, No. 3 and Cove Plantation No. 12 (Russell and others 1970).

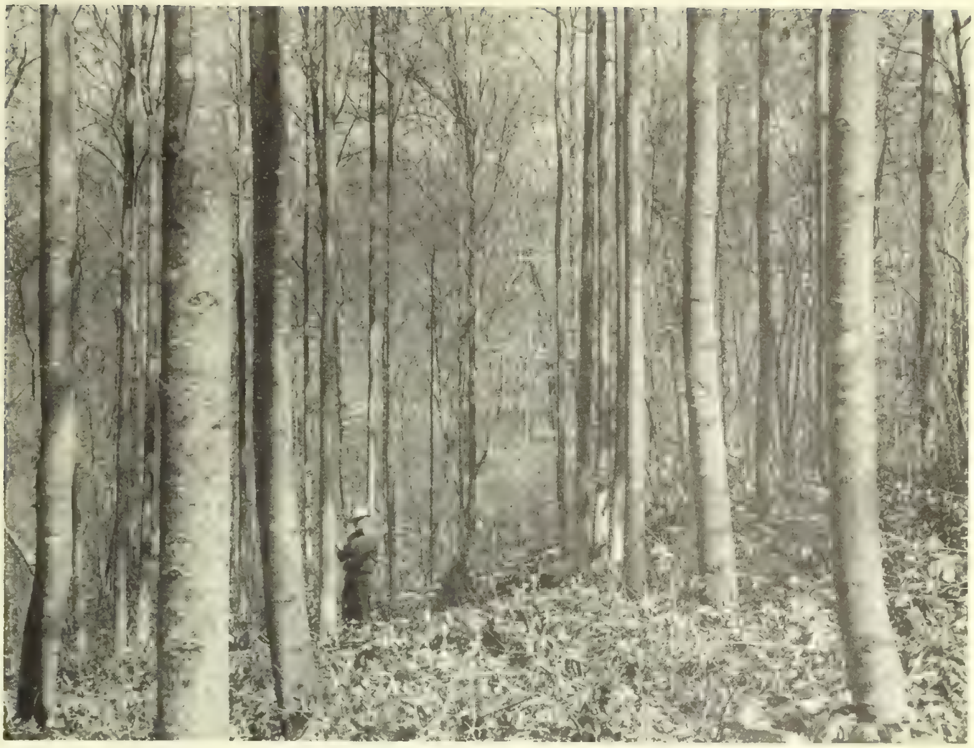

Figure 3.—A 15-year-old plantation on a good Cumberland Plateau site.

throughout the range of yellow-poplar, but many suitable sites on the southern Appalachian plateaus that now support poorly stocked stands of low-grade oaks or oak-hickory are prime examples. Even where natural regeneration is feasible, planting may be desirable to promptly secure desired stand density and species composition. Also, planting is the only way to introduce genetically superior stock when it becomes available.

On hundreds of thousands of acres throughout the range of yellow-poplar unproductive hardwood stands have been or will be converted to pine. But on any tract of appreciable size there are almost always soils suitable for growing yellow-poplar. On these sites, planting yellow-poplar is an available alternative that deserves consideration.

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This review of published research on planting yellow-poplar indicates that workable guides are now available for site selection, planting practices, and competition control. With these guides, land managers can plant yellow-poplar successfully on a wide variety of sites.

Additional keywords: *Liriodendron tulipifera* L. planting, regeneration of hardwoods.

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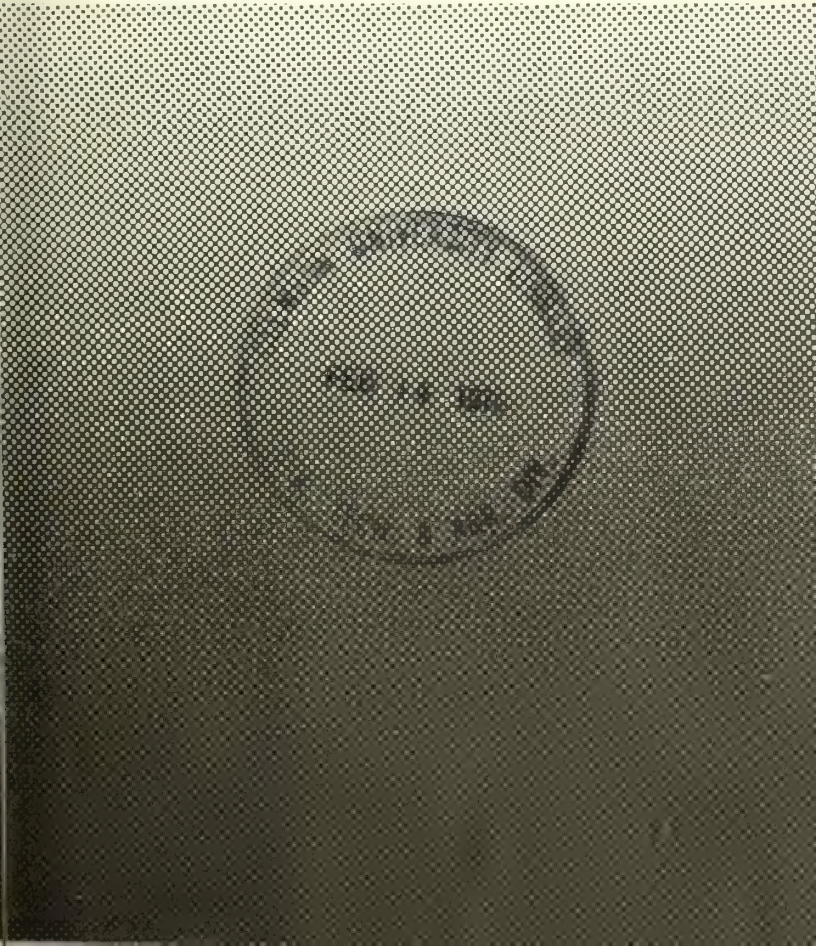

1978

Radiographic Terminology For Biological Research

J. A. VOZZO

Foreword

This glossary is designed for scientists and technicians using diography whose formal education is in other fields. The entries clude terms from related areas such as physics, chemistry, medine, and photography, as they apply to radiography. Other entries purely historical interest are included, since they might be enuntered by the researcher in reading.

To use the glossary effectively, one must have some knowledge elementary radiographic principles and techniques. It can supplement an instruction program. References listed will provide addinal descriptions for the interested reader.

For their reviews I would like to thank Ms. Ann Fox, Director Radiological Training, University of Mississippi Medical Center; r. S. Reid Warren, Jr., Professor of Engineering, University of nnsylvania; Dr. C. E. Dick, National Bureau of Standards; Mr. ger Ney and Dr. Thomas Fearon, National Council on Radiation otection and Measurements.

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sorbed dose. The amount of energy imparted to matter by ionizing radiation per unit mass at a given location; expressed in units of *rad*.

sorber. Any material absorbing ionizing radiation.

sorption. The process whereby particles or *quanta* in a beam of radiation are reduced in number or energy by interaction with either the *nucleus* or *electrons* of the matter they penetrate.

celerator. 1. A device that increases the velocity of electrically charged atomic particles. 2. A sodium carbonate solution that allows the developing agent to break down the protective coating on film.

etic acid. In processing film, an organic acid used during the developing process to remove developer remaining in the emulsion after latent image formation. See *Stop bath.*

tivation. The process of making stable atoms radioactive by neutron bombardment; inducing radioactivity by *irradiation*.

tive. Radioactive. See *Radioactivity.*

tive layer. Fluorescent material (commonly calcium tungstate) in a binding medium used in *intensifying screens*. There is a direct relationship between active layer thickness and the speed of the screen, and an inverse relation between active layer thickness and *resolution* of the radiographic image.

tivity. Number of nuclear transformations occurring in a quantity of material per unit time; measured in *curies*.

tual focal area. That focal area formed at the *filament*, where *electron* streams originate. This electron flow strikes the *target* on the *anode*.

utance. A measure of sharpness of image determined by the distinction of the boundary between the *subject* and *background*. See *Penumbra, Umbra.*

aptation. The adjustment of the eye to dim light or red light necessary when viewing a fluoroscopic image without intensification. Pupil size changes automatically to control the amount of light reaching the retina.

ded filtration. Any filtering material placed in the path of an emitted x-radiation beam after it leaves the *tube*.

hesive. Bonding agent fixing emulsified silver halide gelatin to the polyester base in radiographic film.

Advanced asymmetry. In *tomography,* an asymmetrical expos at the beginning of the tube-film trajectory.

Afterglow. See *Phosphorescence, Lag.*

Agitation. Moving film in solutions during processing. Failure agitate film can result in streaking and loss of uniformity.

Air-contrast. Technique of using air to outline soft-tissue structu for *radiographic contrast* on film. Air-contrast studies requ low to moderate kilovoltage.

Air-dose. Quotient of the mean energy imparted to air by ioniz radiation divided by the mass of air.

Air-gap. Separating *object* and film to reduce *scattered radiat* between them.

Alpha particle (α)**.** A positively charged particle of rad tion emitted from certain *radionuclides.* It is identical to a heli nucleus (2 protons and 2 neutrons) and carries a double po tive charge that strongly ionizes atoms of matter it pass through. Because of its strong ionizing potential, it is not dee penetrative although it leaves the nucleus at 9,000 to 18,0 miles per second. It is absorbed by an ordinary piece of pap

Alternating current (AC). An electric current which periodic reverses its direction in both the coil and the external circ as the armature rotates.

Aluminum equivalent. The thickness of aluminum equal to object to be radiographed; that will offer similar *attenuat* under similar exposure conditions.

Ammeter. An instrument used to measure current.

Ammonium thiosultate. Liquid fixing agent.

Ampere (amp). Unit of electric current; one coulomb per secon

Amplification. Magnifying ionization impulses for measuremen radiation detection instruments.

Amplitude. 1. Maximum height of a wavelength crest.
2. Travel distance of an x-ray tube during a tomograp exposure.

Angiography. Radiography of blood vessels exposed to *cont media*

Angstrom (Å). Unit of linear measure often used to express wa length; 10^{-8} cm.

Anion. A negatively charged *ion*, attracted to the *anode.*

Annihilation reaction. The combining of a *positron* with a ne tive *electron* giving rise to two *photons* moving in opposite directions.

ode. The positive *electrode* of an *x-ray tube.* Negatively charged electrons are attracted to the *anode,* which then releases the x-rays. Anodes may be either stationary or rotating. The quality of an anode may be expressed by its effective *focal spot* size.

ode-grounded tube. See *End-grounded tube.*

SI. American National Standards Institute.

ero-posterior (AP). A *subject* position where x-rays enter the anterior portion of the subject and exit posteriorly for image production.

erture diaphragm. A device to restrict the *x-ray beam* area and reduce *scattered radiation.* A restriction in x-ray beam area requires an increase in *exposure.*

eriography. Radiography of arteries exposed to *contrast media.*

ifact. Any anomalous structure on a radiographic image that can contribute to misinterpretation.

ificial radionuclide. *Nuclides* made radioactive by bombardment of stable nuclides with subatomic particles in an *accelerator.*

ME. American Society of Mechanical Engineers.

TM. American Society for Testing and Materials.

mmetrical tomography. A tomographic technique using either *advanced asymmetry* or *retarded asymmetry* to avoid streaking *artifacts.*

om. The smallest part of an element capable of entering chemical reactions; it consists of a *nucleus* with *protons, neutrons,* and extranuclear *electrons.* The number of protons equals the number of electrons.

omic Mass Unit (AMU). One-twelfth the mass of one neutral atom of ^{12}C.

omic number (Z). Number of protons in the nucleus of an atom.

omic weight. Mass of an atom expressed in *AMU.*

enuation. Gradual decrease of intensity of radiation as it passes through some material. It is influenced by absorption through interaction with the material's atoms, *scattered* and *secondary radiation* emissions, and the *inverse square law.*

o (a). Prefix meaning 10^{-18}

Automatic brightness stabilizer. A phototiming system automatically increases either kilovoltage or milliamperag compensate for *object* thickness, resulting in good *con* and optimal brightness in the image intensifier.

Automatic film processing. A system incorporating proces transporters, water, recirculation, replenishment, and dryer systems which automatically processes film from develc through dried product. Timing varies from 90 seconds 15 minutes.

Automatic shutter. A sensing device which limits beam size adjusting *focus-film distance* to film format by opening or clo *collimator* shutters.

Autoradiograph. An image produced on a sensitized surface radiation emanating from radioactive materials within the sp men examined.

Autotomography. A limited, difficult tomographic procedure which the object is rotated beneath a stationary x-ray tube dur exposure which allows only images of points within the of rotation to be in sharp focus.

Autotransformer. A transformer in an x-ray generator that all the x-ray tube easily variable output voltage (within a limi range).

Average gradient. A numerical expression of the relative aver contrast properties of a film and processing combination a specified exposure; represented by the slope of a straight l connecting specific density points on a *characteristic curve.*

Background. Presence of ionizing radiation in the environm from both external emissions (*cosmic rays*, natural *radio clides*) and internal emissions (from *object* of radiograph, r terial of instrument).

Back-reflection method. An x-ray diffraction method using *mo energetic* x-rays and material foils that are thick enough diffract the radiation back to the film for image forming.

Backscatter. Radiation deflection by scattering rays in the *objec* angles greater than 90° from the entering *primary ray.* T increases the object's radiation exposure and fogs the film can sometimes be arrested by placing a lead sheet bene the film.

Backup timer. A *phototimer* that controls the maximum expos in a radiographic tube.

Ballistic mAs meter. A mechanism registering *milliampere-s* *onds* (mAs) for x-ray units operating in excess of 200 *mA*. In exposures of less than 0.1 sec, an ordinary ammeter can not register exposure accurately, so the mAs is determined by connecting the meter with an impulse timer.

rium clay. A molding clay used to reduce the amount of *scattered radiaion* intercepting the film. The clay is formed around an irregularly shaped object. The clay itself can be a source for additional scattering.

rium lead sulfate. A fluorescent chemical that emits a visible blue-violet light when activated by x-radiation. It is used in *intensifying screens*.

rium platinocyanide. Historically important as the fluorescent layer on cardboard used by *Roentgen* in his original fluoroscopic process.

rium sulfate. *Radiopaque* contrast medium. Using barium sulfate may require higher kilovoltage than usual.

rrier. Protective shields of radiation-absorbing material. Thickness of material depends upon its absorbing qualities, the source of radiation, and distance from source to protection area. Commonly used materials are lead and concrete. Air is adequate when sufficient distance is practical.

se. A transparent plastic (usually polyester) about 0.008 inch thick used to hold the emulsion layer of radiography film.

se density. The minimum *density* of a film. It is a function of light absorption by the plastic base and the base dye and does not include the emulsion layer.

se film. In *subtraction*, the original *radiograph* used to produce the mask.

se fog. See *Base density*.

am. A directed flow of electromagnetic radiation.

cquerel, Henri. Reported in 1896 that uranium emitted rays which could pass through paper and darken a photographic plate in a dark room.

ta emitter. Source of beta radiation; a radioactive atom.

ta particle (β). Strongly ionizing electron ejected at high speeds from certain radioactive materials.

tatron. An accelerator used to produce electron beams and high energy x-rays by accelerating moving electrons in an alternating magnetic field.

BeV. Billion electron volts.

Binding energy. Energy holding together *protons* and *neutrons* the atomic *nucleus.*

Biological burden. In radiography, the amount of any acqui radiation in a biological system per unit of time.

Biological half-life. In radiography, the time required for a biological system to naturally eliminate one half of an acquir *dose.*

Biplane studies. A technically difficult simultaneous exposure two films, each in a separate plane, which allow clarificati when interpreting problems created by overlap.

Blocking. See *Masking.*

Body-section radiography. See *Tomography.*

Bragg's law. A mathematical expression used to determine t positions of crystalline structure as imaged in x-ray diffractio $n\lambda = 2\ d \sin \theta$, where n = order of the spectrum, λ = wav length of the x-rays, d = distance between atomic planes, a θ = the angle between the diffracted x-ray and the atomic plar

Bragg method. An x-ray diffraction method using monoenerge x-rays and a rotating crystal.

Braking radiation. See *Bremsstrahlung.*

Bremsstrahlung. "Braking radiation" (German). A process which electrons are deviated from their original path by stron positive nuclear fields and decelerated, transforming some their original energy to an x-ray of equivalent energy. Bremm strahlung is composed of *heterogeneous* beams.

Bright fluoroscopy. See *Image intensification.*

Brightness gain. An increase in illumination of 4,000 to 7,000 tim for viewing *fluoroscopy.* The electron energy of the forme image is converted through an optical system to an image on closed circuit television or cine recording.

British thermal unit (BTU). The amount of heat required raise the temperature of one pound of water one degree Fahre heit at atmospheric pressure.

Bucky. Commonly used to refer to the entire *Potter-Bucky grid* an moving mechanism.

Bucky grid. A stationary grid of 60 to 110 alternating parall strips of lead and plastic placed between the object and film t reduce *scattered radiation.* Gustave Bucky designed it in 191

nsen-Roscoe reciprocity law. The end result of a photochemical reaction is dependent only on the product of the radiation intensity (I) and the duration of the exposure (t), and is independent of absolute values of either quantity.

binet x-ray system. An x-ray system completely enclosed in one housing.

lcium tungstate. A naturally occuring mineral or synthesized crystal that fluoresces with x-radiation to emit visible blue-violet light. It is used in *intensifying screens.*

libration. Instrument standardization in relation to a known standard.

nting. The manufacturing process allowing grids to be produced flat while their lead lines are inclined to provide the correct fixed *focus-film distance.*

pacitor-discharge unit. A mobile x-ray generating unit that operates by storing electricity in a capacitor. The electricity may then be discharged through an x-ray tube.

rdboard film holder. A film holder made of any lightproof paper; requires darkroom loading.

ssette. A sturdy, lightproof container with a *radiolucent* front used for holding radiographic film during exposure. It may also have *intensifying screens* and/or *filters.*

thode. The negative electrode of an x-ray tube. The cathode terminal consists of a filament, supporting wires, and focusing cup.

ion. A positively charged ion attracted to the cathode.

nti (c). Prefix meaning 10^{-2}.

ntral beam. X-rays in the center of a generated beam. The beam usually does not have a homogenous intensity throughout because of the *heel effect* from the *anode.*

halopelvimetry. A technique developed to calculate the relative sizes of a fetal skull and the maternal pelvis using image geometry. It can be used to determine actual subject size from any enlarged image when values are known for the enlarged image, *FFD,* and *OFD.*

lky radiographic contrast. Low *contrast* on radiographic film that impairs image interpretation.

mberlain-Towne projection. A technique using an angle of beam projection with less than 90° between the tube and the object-film plane. This results in greater *parallax effect* perpendicular beam projection.

Characteristic curve. A curve that expresses the relation betw the image density and the amount of exposure of a radiogra film. Exposure is usually expressed by logarithm. The ne straight portion of the slope of the curve represents maxin contrast; values from the shoulder and toe of the slope proc low contrast.

Characteristic radiation. Discrete energies emitted from a ta element that characterize the target. The energy is produ by an inner-orbit electron collision. The amount of energ leased equals the amount of energy required to remove inner-orbit electron, which in turn is characteristic of the ta element. See *Monoenergetic beam.*

Cholangiography. Radiography of bile ducts exposed to *con media.*

Chrome alum. An additive in the emulsion gelatin of radiogra film which hardens the film to protect against scratching.

Cinefluorography. See *Cineradiography.*

Cineradiography. A method of permanently saving a fluorosc image on photographic film. Although the technique requ film processing, it affords better resolution and better quality motion replay than video tape.

Clearing time. The time it takes for *fixer* to dissolve undevelo silver halide; characterized by disappearance of milky diffu on film after it is placed in fixer solution.

Coherent scattering. *Scattering* produced by interaction very low-energy *photon* with a bound orbital *electron.* scattered photon has the identical wavelength of the er ing photon, but a different direction.

Cold tube. See *Field emission x-ray tube.*

Collimation. A process changing a diverging beam of radia into a useful parallel beam by means of lead *collimators.*

Collimator. A device that accurately delimits beams to a sh image, reducing the *penumbra.* Collimators have variable a tures, can automatically adjust to any cassette size, and usu have a beam-centering device.

Comets. Artifacts produced on film that resemble comets. They usually caused by rust particles adhering to film during deve ment.

mpensating filter. Any material that can produce an image of more even density on a radiographic film by compensating for varying object opacities.

mpton effect. A phenomenon of attenuation. *Scattered radiation* is produced when loosely bound outer-shell electrons are bombarded by photons. The electron changes velocity after collision with a photon and is then called a Compton electron. The photon is reduced in energy and has a longer wavelength. The photon's velocity is also changed and it is now known as a scattered photon. As scattered radiation, such photons cause film fogging.

ne. A conical metal tube used to restrict the area of an x-ray beam.

ntrast. Interpretation of density differences which are the result of relative silver distribution on developed film. See *Radiographic contrast, Subject contrast,* and *Film contrast.*

ntrast improvement factor. The ratio of radiographic contrast with a grid to contrast without a grid.

ntrast medium. A *radiopaque* or *radiolucent* material used in an object which allows differentiation of density by selective absorption of the material.

ntrolled area. An area where radiation sources are used. Protection of all personnel is afforded through procedures of construction, access, and exposure.

nvergence line. The intersection of imaginary lines that extend upward from the planes of tilted lead strips in *focused grids.*

nversion factor. The ratio of the brightness of the output screen to the rate of exposure of radiation at the input screen. A standard, as proposed by ICRU, which specifies the intensifying ability of any given x-ray image intensifier.

nverter foil. A metal foil (gadolinium, rhodium, indium, or cadmium) exposed during *neutron radiography* of an object. The foil then emits beta or gamma radiation, producing an image on film.

olidge tube. A hot cathode diode tube commonly used to produce x-rays; invented by W. D. Coolidge in 1913.

oling curve. The graphic relation between heat accumulated in an x-ray tube and the time it takes for the tube to cool.

ona. A blue electrical discharge surrounding a high voltage conductor caused by air ionized by current leakage.

uscular theory of radiation. A theory explaining the movement of x-rays as that of photons travelling at the spee light and bearing no electrical charge.

Cosmic rays. High energy electromagnetic radiation of extre short wavelength, originating outside the earth's atmospher

Coulomb (C). A unit of electrical charge consisting of one *am* second.

Cradle. A mechanical device for rotating or positioning a su for radiographing.

Crimp marks. Curved lines, one or two cm in length, resu from bending film sharply. Marks will be white if occuring b exposure, and black if occuring after exposure.

Cross-hatch grid. Any two stationary grids placed one on to the other so that the lead strips in each are at right a to each other. See *Moire pattern.*

Cumulative dose. The total dose of repeated radiation expo received by an *object.*

Curie (Ci). A unit of measure for the disintegration rate of a sa of radioactive material. Specifically, any radioactive source a decay rate of 3 x 10^{10} disintegrations per second.

Curie, Marie and Pierre. Discoverers of polonium and ra (1898) for which Marie invented the term radioactivity.

Cutie pie. Popular name for a battery-operated portable monit device. It is an ionization-chamber ratemeter used to detect and gamma rays in the range of 1 to 5000 mR/hr.

Cyclotron. A particle accelerator which uses a magnetic field t celerate a positive ion beam by alternating electric fiel maintain the high speed particles in a spiral path. Used fo clear research and to produce x-rays.

D-log E curve. See *Characteristic curve.*

D-max. The maximum *density* that can be produced on a film.

Dark adaptation. A 20- to 30-minute period spent in nearly plete darkness which enables the retina of the eye to adju viewing low-light sensitivities such as those encountered in ventional fluoroscopy. Red-adaptation goggles may also be

Daylight system. A technique combining film holders and matic processing that eliminates dark room requirements.

Dead-man switch. A safety switch that closes a circuit on continuous pressure from the instrument operator.

Debye-Scherrer method. A method using diffraction of *n* *energetic* x-rays to identify a powdered specimen packed in a glass capillary or adhering to a ribbon of x-ray transparent material.

eci (d). Prefix meaning 10^{-1}.

efinition. Sharpness of detail or clarity of lines in a radiograph: a major factor in radiographic quality. It is determined primarily by factors of geometry, film, and radiation. See *Acutance.*

egassing. A technique used in assuring the high vacuum necessary in the envelope of x-ray tubes. The tube is heated to expel gases entrapped in the component parts.

eka (da). Prefix meaning 10.

ensitometer. An instrument used to measure *density.* For transmitted density, a photocell gives direct readings; for reflected density values, a series of printed, standard density values is compared to the unknown for an approximate match.

ensity. The amount a radiographic film darkens as a result of radiation interacting with silver halide crystals in the emulsion.

$$\text{density} = \log \frac{\text{incident light}}{\text{transmitted light}}.$$

ensity gradient. A numerical value that refers to *contrast* values on film; the higher the number, the higher the contrast. It is determined from a film's *characteristic curve* by dividing the value of the vertical rise by the value of the horizontal rise.

epth dose. Radiation *dose* at a specific depth within an object. It is usually measured in percentage of surface dose.

epth localization. A means of determing the location (depth) of an object within a *subject* using either *stereoradiography, tomography,* or the *parallax method.*

etail. Sharp, clear delineation of objects in a radiograph. See *definition.*

etection. Any of several methods used to indicate the presence of x-rays; the methods can be photographic, fluorescent, ionizing, or physiological.

etergent rinse. A technique used to shorten film drying time. After final washing and before drying, films are rinsed in a weak detergent solution (5 ml/41 ml of water).

eveloper. The chemical solution that converts the latent image on film to a visible image. It consists of a developing agent (hydroquinone), an accelerator (sodium carbonate), a preservativ (sodium sulfite), and a restrainer (potassium bromide) to prever unexposed silver bromide crystals in film from blackening.

Diaphragm. A simple device for restricting the primary x-ray bear and reducing *scattered radiation*. It is usually used as a component of another device such as a *Potter-Bucky diaphragm.*

Diffraction mottling. A mottled, diffuse diffraction pattern on radiograph.

DIN. Deutsche Industrie Norm. (German Standards Organization).

Diode. 1. An electron tube with two electrodes (anode and cathode 2. An electrical rectifier with a semiconducting crystal and tw electrodes.

Direct current (DC). An electric current which flows through conducter continually in one direction.

Direct-exposure film. See *Nonscreen film.*

Direct-positive film. A contact film used to duplicate radiograph which maintains the same positive-negative densities.

Disc. See *Rotating anode.*

Discography. Radiography of intervertebral discs exposed to *contrast media.*

Disengagement. A technique used in *tomography* that erases images in the *object* along the beam path to allow better *subjec* resolution.

Distance. See *Inverse Square Law.*

Distortion. A false representation of an *object's* true size and shape

Dose. The amount of radiation or energy absorbed by an object per unit mass; measured in *rads.*

Dose equivalent (DE). An expression used in radiological *health* to express the effective absorbed dose, measured in units of *rem*. By definition of *ICRU*: H = QND. H = dose equivalent, Q = quality of beam, N = product of other modifiers, D = *absorbed dose.*

Dose rate. Amount of radiation per unit time received by an object; measured in *rems* per hour.

Dosimeter. An instrument that detects and measures radiation dose, such as *film badge* or *ionization chamber.*

Dosimetry. Measurement of the amount of radiation delivered to or absorbed at a particular point or area.

ouble-coated film. Radiographic film with an *emulsion* layer on both sides.

ouble exposure method. See *Parallax method.*

ouble focus tube. An x-ray tube with two *filaments* mounted side by side. The filaments are of different sizes and produce correspondingly different *focal spot* sizes. The focal spot size can be selected by a control switch.

ryer system. A rapid-drying mechanism in the *automatic film processor.* It uses a series of squeeze rollers to remove surface moisture from the film and a forced hot air system to complete drying.

rying. Film must be dried after washing. This is accomplished with controlled heat or time. A detergent rinse after washing will shorten drying time.

uplication. A technique for photographically reproducing a radiographic image.

uplication film. A direct positive photographic film used to duplicate radiographs.

uplicating printer. A light-controlled, exposure regulating device for duplicating radiographs by exposing copying film.

ison, Thomas A. Invented *fluoroscopy* and the *fluoroscopic screen* in 1896.

ective focal area. The actual focal area of electrons at the *object.* Electrons originating at the *filament* strike an area on the *target* and are reflected at right angles. The focal area at the object is only a fraction of the focal area at the target. The effective spot area is critical to good radiographic *definition.* The smaller the effective focal spot, the greater the definition. The angle of the target (*anode*) to the filament determines the effective focal area by simple geometry. A 10° to 22° angle is common.

Eectual voltage. In a self-rectified circuit, the current passes through the x-ray tube for only a half-cycle of effective voltage and no current flows during the second half-cycle.

Elctrolytic silver recovery. The process of recovering plated silver deposited on the cathode. An electric current is passed between two electrodes placed in used fixer solution.

Elctromagnetic radiation (EMR). An energy form radiated at right angles to the direction of electron travel when the velocity of the electron is changed. All forms of EMR originate from an electric particle, travel at the speed of light, and exhibit wa motion.

Electromagnetic spectrum. The inclusive range of all forms electromagnetic radiations, radio, infra-red, visible light, ult violet, x-ray, gamma, and cosmic energies.

Electromotive force (emf). The potential difference between el trodes which allows current flow; measured in volts.

Electron. An elementary, negatively charged particle.

Electron emission. Liberation of electrons by heat, light, fi emission, or bombardment by other radiation.

Electron emission radiography. Technique of exposing a spe men to *hard x-rays* through the film. The object is distinguish by emissions, depending on its atomic number. This is call reflection microradiography in Europe.

Electron impulse timer. Timer that uses thyratron tubes to me ure one impulse accurately (1/120 sec). All exposures are ma in multiples of one impulse.

Electron radiography. A technique in which *hard x-rays* strik lead screen which then emits electrons to the *object.* The s *ject* should be thin and have a low atomic number.

Electron volt (ev). The amount of energy gained by one electr passing through a potential of one volt; 1 ev = 1.6 x 10^{10} er

Electronic timer. A timer accurate to 1/10 second.

Electroscope. An instrument used to detect electric charges displacement of an electrically charged component of the inst ment.

Electrostatic latent image. The latent image produced in *xer raphy* by photon excitation of selenium crystals on an alumin plate.

Emulsion. A suspension of silver bromide crystals in thin gela coating on the film base. It is characterized by its *speed* a *latitude.*

Emulsion fog. The minimum *density* of film possible because spontaneous unexposed crystal development during long de opment and processing of fast films.

End-grounded tube. A long, narrow x-ray tube useful for pr type instrumentation. It emits a 360° beam. The anode s of the high voltage pole is grounded and therefore requ no electrical insulation. It is also called an anode-grounded tube or a rod-anode tube.

largement. Radiographic enlargement necessitates the use of one of two special processes. A simple photographic enlargement is unacceptable because grains in the radiographic film are magnified, as are *grid lines*, when present. Radiographic enlargement (direct roentgen enlargement) requires changing the geometry of *FOD* and *OFD* with an x-ray tube with a *focal spot* 0.3 mm or less, from which enlargements up to 3x linear or 9x area are possible. The other technique uses medical *fluoroscopy* with an *FFD* of at least one meter.

velope. A glass tube surrounding the electrodes of an x-ray tube inside which a vacuum is maintained.

uivalence factor. A guide used to approximate the relative *penetration* by x-rays of materials with different *atomic numbers*. Aluminum is the standard at low Kv while steel is the standard for high Kv and gamma rays.

ythema. Blood distension in skin capillaries resulting in redness. It is caused by x-rays, heat, drugs, or ionizing radiation.

xit radiation. See *Remnant radiation*.

xpiration date. The date after which the manufacturer of a film will no longer maintain the warranty for quality control.

xposure. Amount of radiation generated in standard atmosphere that is measurable in units of *Roentgen*.

xposure angle. The arc through which the x-ray beam moves during a *tomography* exposure; the larger the angle, the thinner the section shown on the film. Zero degree angle is normal radiography.

xposure chart. A graphic relation that gives exposure values for materials of uniform thickness, taking into account *peak kilovoltage (kVp)* and exposure (in *mAs*). It is impractical for biological specimens.

xposure factor. Represented by the formula: $\frac{\text{milliamperes x time}}{\text{distance}^2}$

xposure rate. Radiation exposure per unit of time, measured in R/min. It may be controlled by varying tube current, tube potential, distance from tube to *object*, or amount or kind of filtration.

xtended traverse radiography. A form of in-motion radiography where the source moves along a linear path to cover a long, narrow subject.

Femto (f). Prefix meaning 10^{-15} .

Field emission x-ray tube. A specially designed tube that e x-rays by using very high voltage to expel electrons from a metal (field emission).

Filament. A small coil of wire (usually tungsten) mounted in a m shield that releases free electrons when heated in a vacuum *velope.*

Filament evaporation. Gradual erosion of the *filament* cau by prolonged use.

Filament current. A low voltage current used to heat the *ment.* Increasing filament current increases filament tempera which increases the rate of electron emission. One of the w leading to the filament carries the high voltage necessar propel electrons to the target.

Filament stabilizer. A capacitor and transformer arranged to vide nearly constant filament current by compensating for line voltage changes that may occur during exposure.

Film. A transparent, flexible polyester base coated with a silver ha emulsion suspended in gelatin. The emulsion is sensitive portions of the electromagnetic radiation spectrum (incluc visible light and x-rays) which can form a latent image wh becomes visible when processed.

Film badge. A light-tight package of filters and films of vari sensitivities worn to monitor exposure to radiation. The deg of film darkening allows the *absorbed dose* to be calculated.

Film contrast. *Radiographic contrast* attributed solely to inher properties of the film and the manner of processing.

Film hanger. A device to attach radiographic film to a rigid fra used to transport film during manual processing.

Film intensification. The process of enhancing the *density* underexposed film. It can be accomplished even after the f has been fixed and dried.

Film latitude. The exposure range that is most effective for a giv film. Film latitude and *film contrast* are reciprocal. High contr film usually has less latitude than low contrast film.

Film marker. Lead numbers and letters which can be placed a film before exposure to identify subject, date, and conditic of exposure.

Film plane. Position of the film in relation to the x-ray beam a the subject. An important factor in the geometry of good radiographic images.

in side. That side of a *subject*, film holder, *cassette*, or *grid* that is placed adjacent to the *film plane*. Proper orientation of film is especially critical when using multi-pack film or *focused grids*.

in speed. A measurement of the quantity of radiation necessary to produce a designated image *density*. A fast film takes less radiation to produce the same density than a slow film. Relative film speed may be determined from a *characteristic curve* by plotting several films on the same graph.

n streaking. *Artifacts* caused by failure to stir processing solution, or by inadequate agitation of film in developer or fixer, or by insufficient rinsing.

ter. 1. Any substance that attenuates x-radiation after it leaves the *target*, such as the glass *envelope* of the tube or metal filters placed outside the tube. The purpose of a filter is to absorb longer wavelengths emitted from the target and allow the harder x-rays to reach the subject.

2. A device used to reduce the intensity of illumination in a darkroom by selective absorption of light.

tration. A technique of hardening the quality of an x-radiation beam reaching the subject by using a filter to selectively absorb softer radiation from the beam.

er. A solution of ammonium thiosulfate for removing unexposed silver halide crystals from film. It also includes aluminum chloride for hardening the gelatin, acetic acid as a buffer, and sodium sulfite to lessen colloidal sulfur formation. Fixers used in automatic processors unlike those used in manual processing are usually highly acidified, and buffered automatic processors do not usually employ stop bath.

sh radiography. An instrument with very high voltage capability that produces short but intense x-ray flashes (see *Field emission*); useful for high speed, rapid motion subjects.

orescence. In radiography, a phenomenon whereby certain substances such as calcium tungstate receive x-radiation and emit radiant energy of a visible wavelength.

orography. See *Photofluorography*.

oroscopic screen. A screen coated with zinc cadmium sulfide crystals which emit a yellow-green visible light when struck by x-rays.

Fluroscopy. A technique whereby a radiographic image is int fied and viewed directly rather than as a latent image on fn. Two procedures are available, dark and intensified fluorosc y. In dark fluoroscopy, the image is viewed as green light em d from a zinc cadmium sulfide screen. This is an inefficient vie g system which requires viewing in a darkened room. Intens d fluoroscopy uses electronic image intensifiers to increase e brightness of the image about 6,000 times which allows vie g in ordinary light through television or cineradiography.

Focal spot. The area where the electron stream discharged fron e filament strikes the anode *target.*

Focal track. On a rotating *anode,* the circumferential area at actually receives the electron impact, producing a *focal spo.*

Focus-film distance (FFD). Distance between the *focal spot* d the *film plane.*

Focus-grid distance. The distance between the tube focus d grid surface that can be used without excessive *grid cutoff.*

Focus-object distance (FOD). Distance between the *focal* pt and object to be radiographed.

Focus-plane distance (FPD). In *tomography,* the distance tween the *focal spot* and the *objective plane.*

Focused grid. A grid with its lead strips slanted to conform to e angle of the primary ray, which diminishes *grid cutoff.* See (*vergence line.*

Focusing cup. A negatively charged *cathode* component (usu y made of molybdenum) placed behind the *filament* to focus t electron beam and keep it on a narrow path towards the *tar*

Focusing distance. The vertical distance from the *converge line* to the center of a *moving grid.*

Fog. The minimum overall *density* of radiographic film; *base de ty* plus *emulsion fog.* Fog reduces image quality.

Forward scatter. Radiation scattered in the same direction as t primary beam.

Fractional-focus tube. A special x-ray tube with a *focal spot* of mm or less. Used in direct image enlargement.

Freeze. Image retrieval from image storage systems (such as a vi disc scanner).

Frequency. Number of cycles per unit of time; measured in *Her*

Frilling. Separation of emulsion from film base. Usually caused wash water or processing solutions being too hot.

lcrum. In *tomography*, the convergent point of the beam common to the shifting tube and the film shift. The fulcrum level determines the *objective plane*.

dolinium oxysulfide. Rare earth phosphor (manganese activated) used in radiographic *intensifying screens*; emits primarily green light.

amma. The slope of the straight-line portion of a *characteristic curve*. It measures contrast.

amma rays (γ). Electromagnetic waves distinguished from x-rays by having a nuclear origin.

aseous burst agitation. A technique of automatically aerating film that is being processed manually. An inert gas, usually nitrogen, is released into the tank. Bubbles then agitate the film.

eiger counter (GM). Geiger-Muller (GM) counter. An electronic radiation detector that counts individual photons and is particularly efficient for beta particles.

el swell. The action of an accelerator (sodium carbonate) in the developer that swells up the gelatin, speeding development.

elatin. A colloidal, amphoteric matrix that fixes silver halide crystals to the film emulsion layer.

eneral radiation. See *Bremsstrahlung*.

enerator. In radiography, a device that provides electrical potential to the x-ray tube for electron acceleration.

eometric unsharpness. See *Penumbra*.

eometry. In radiography, the spatial relation of the image producing factors *(FFD, FOD, FPD)* to the latent image.

iga (G). Prefix meaning 10^9.

radient. An objective measure of *film contrast* calculated from a *characteristic curve* for that film. The higher the gradient value, the higher the film contrast at that same kV.

raininess. Uneven *density* observed in film image caused by distribution of silver halide crystals in emulsion, particularly in fast film where large crystals have uneven distribution. See *film speed*.

renz Rays. X-rays produced in the 5 to 20 kV range.

rid. 1. An apparatus placed between the subject and film, composed of alternating lead and radiolucent strips fixed vertically, in line with the tube's *focal spot*. The lead strips absorb photons of *scattered radiation* from the subject, while the *radiolucent*

material allows the primary radiation to pass and expos he film. Grids are generally classified as stationary or moving.
2. An electrode (See *Grid-controlled x-ray tube*).

Grid bias. The negative potential in kV between the *grid* and e *anode* in a *grid-controlled x-ray tube* (triode). The nega te charge applied to the grid can interrupt electron flow to e anode and offer more exact control of tube current.

Grid cassette. A cassette with a built-in *grid*.

Grid-controlled x-ray tube. An x-ray tube with three electro s, *anode, cathode*, and *grid*. The grid is placed between the fi- *ment* and *target* and regulates the flow of *space charged* e trons by grid bias.

Grid cutoff. Underexposure on one side of the radiograph cau d by poor alignment of the x-ray beam with the *grid*.

Grid efficiency. A grid's ability to minimize *scattered radiation*.

Grid lines. 1. Images on the film caused by shadows of the l d strips.
2. The number of lead strips per inch on a *grid*.

Grid radius. See *Convergence line*

Grid ratio. An expression of the ratio of height of lead strips the grid to the distance between the strips, $r = h/d$ where r = grid ratio, h = height of lead strips, and d = distance betwe lead strips. A higher grid ratio means greater grid efficiency, th greater image detail.

Grid specifications. *ICRU* recommends that five specifications furnished with each focused grid: *grid ratio*, number of le strips per inch, *focusing distance*, *focus-grid distance* limits, a *contrast improvement factor.*

Guide marks. An *artifact*. Uniform scratches on film caused by i properly adjusted guides and rollers in an automatic processo

Gurney-Mott theory. A theory proposed in 1938 by Gurney a Mott to explain the formation of a latent image by silver hali after photon capture. The silver halide crystal is struck by a ph ton which liberates an electron from a halide ion. Additional ele trons gather at the site of photon capture, which becom negatively charged. This attracts positively charged silver ions the site which then becomes neutralized, forming metallic silv Processing converts the latent image into a visible one.

H and D curve. Hurter and Driffield curve. See *Characteristic cur*

alf-life. The time in which one half the atoms of a radioactive material disintegrate into another nuclear form.

alf value layer (HVL). The thickness of any material that reduces the *dose rate* of an x-ray beam to one-half its initial value. See *Filter*.

alides. A chemical term for the salt-forming compounds of fluorine, chlorine, bromine, iodine, and astatine.

ard x-rays. A common term meaning a beam of relatively high energy and short wavelength. A hard x-ray beam may be produced by filtering out *soft x-rays* with aluminum or copper.

ardening agent. An additive (usually glutaraldehyde) in *developer* for automatic processing; it reduces *gelatin swelling*. See *Fixer*.

ealth physics. The application of radiological safety techniques to recognizing, evaluating, and controlling the effects of ionizing radiation and the use of its generating equipment. Both subject and operator must be protected from radiation and high voltage electrical apparatus. Each user is also responsible for the effects on nearby organisms.

eat dissipation rate. The rate at which heat energy is transferred away from an *anode*; measured in heat units. Cooling curves are supplied by the tube manufacturer to help avoid prolonged tube heating from excessive exposures.

eat storage capacity. The ability of the *anode* to store heat energy during exposure without damage. Exceeding the manufacturer's heat storage capacity with short, numerous exposures will significantly shorten the life of an x-ray tube.

eat Unit (HU). The unit of measure for heat energy generated at the anode during exposure. 1 HU = kV × mA × sec.

ecto (h). Prefix meaning 10^2.

eel effect. A decrease in the exposure rate of an x-ray beam toward the edges of the beam. The variation is greatest (less exposure) on the *anode* side of the beam. Heel effect is also greater with an increase in *FFD* or film size.

elium (He). See *Alpha particle*.

ertz (Hz). Unit of measure of radiation; cycles per second.

eterogeneous x-rays. A usual x-ray beam consisting of photons of wavelengths that vary from 0.05 Å to 1000 Å. See *Bremsstrahlung*.

ot tube. See *Coolidge tube*.

Housing cooling. A mechanism that dissipates heat generat the *anode;* usually an oil bath between the tube *envelope* the housing. See *Heat dissipation rate.*

Hydroquinone. In film processing, an organic reducing agent in *developer.*

Hypo. See *Fixer.*

Hypo eliminator. In film processing, a chemical added betw fixing and washing to reduce the amount of time and volu of water required to complete manual processing.

ICRP. International Commission on Radiological Protection.

ICRU. International Commission of Radiation Units and Meas ments.

Illuminator. A device that allows a *radiograph* to be viewed wit glare by evenly diffusing enough light through it, over its en area.

Image distributor. An optical device used to split the beam fr an output *phosphor* enabling several channels to carry image. Channels might be for mirror viewing, *cineradiogra* or strip filming.

Image intensification. An electronic system that intensifies an dinary fluoroscopic image about 5000 times. An image inte fier converts the *x-ray* image patterns into visible light patte which are then shown on a video screen.

Image quality indicator. See *Penetrameter.*

Image receptor. Any device that can transform x-ray photons i a visible form.

In-air exposure. Exposure rate measured at any given point i beam with no scattering material in the beam path. Measu in units of R/min. In-air exposure = R/min × time.

Incoherent scattering. Scattering of photons resulting in loss energy by the photon.

Industrial radiography. Application of radiography to indust needs. It requires energies capable of penetrating subjects rar ing from oil paintings to steel structures.

Inherent filtration. Any material filtering x-radiation emitted fr the *target* through the tube, such as a glass *envelope,* oil coola or other housing materials.

In-motion radiography. A special technique in which a movi source traverses a stationary subject or vice-versa; used in tended linear traverse radiography, *rotary rotation* radiography, *orthogonal* scanning, and *tomography.*

Insulating oil. An oil used to prevent high voltage sparking between terminals of a radiographic tube. Terminals are immersed in insulating oil between the envelope and a metal housing.

Intensifying factor. A value used to achieve particular film *density* when exposing film with *intensifying screens.* Intensifying factor

$$= \frac{\text{exposure without screens}}{\text{exposure with screens}}.$$

Intensifying screen. A composite of fluorescing material (usually calcium tungstate) and binder which is used with film to convert photon x-ray energy into visible light. The amount of light emitted is in direct proportion to the intensity of x-rays striking the *phosphor.* The image developed on the film is intensified by the fluorescing calcium tungstate.

Intensity. Amount of energy per unit of time passing through a unit of area perpendicular to the beam direction.

Interaction. Effects resulting from photons physically associating with atoms of material in their path. Some interactions are: *photoelectric process, coherent scattering, Compton effect,* and *pair production.*

Interlock. A safety device that prevents generation of x-rays at the source until radiation shielding is properly aligned.

ntermediate voltage. The energy range from 130 to 150 kV.

nternal scatter. Scatter produced by photons striking and interacting with materials inside a *subject,* that may cause a blurred image.

ntravenous pyelography (IVP). Radiography of kidneys, ureter, and bladder exposed to *contrast media.*

nverse square law. The intensity of the *source* at the *subject* is inversely proportional to the square of the distance from the source to the subject.

on. An electrically charged atom or molecule.

onization. The addition or removal of electrons from atoms or molecules. X-ray energies may produce ionization.

onization chamber. An instrument that detects and measures ionizing radiation by measuring electrical current produced when the incoming radiation ionizes the gas in the chamber, making it act as a conductor.

Ion pair. Two *particles*, an *electron* and a positively charged residue that are the product of ionizing radiation interacting with orbiting atomic electrons.

Irradiation. *Radiation exposure.*

Isotopes. Atoms (of the same element) with the same atomic num ber but with different atomic weights.

Jerman, Ed C. A contemporary of Roentgen, Jerman began a instruction program in radiography for physicians and techn cians in 1897.

Jig. A device used to fix an object in a position to be radio graphed.

K shell. An energy level associated with an inner electron shell an atom. It is the usual site of photon excitation during photo electric interaction, which produces characteristic x-rays. See *shell.*

Kenotron. See *Valve tube rectifier.*

Kilo (k). Prefix meaning 10^3

Kilovolt (kV). An electrical potential difference of 1000 volts.

Kilovoltmeter. A voltmeter wired with an *autotransformer* that a lows the primary voltage to be pre-set for an exposure.

Kinescopic image. Direct image photography from a televisio screen; photos from television fluoroscopy.

Kymography. A specialized technique for viewing a moving subje by a sequential series of exposures and using a special grid.

L shell. An electron shell level of an atom that has less energy tha the K shell, and that usually fills the K shell when an electron removed. When this occurs, an x-ray is emitted with *characte istic energy* equal to the potential between the two shell energ levels. See *K shell.*

Labyrinth. See *Light lock, Maze.*

Lag. See *Screen lag.*

Laminography. See *Tomography.*

Lanthanium oxysulfide. See *Gadolinium oxysulfide.*

Latent image. The image formed by the interaction of x-ray ene gies with silver halide crystals in film *emulsion*. The latent imag is invisible and must be developed to a permanent or *manife image.*

Lateral projection. Transverse passage of x-rays through a *subje*

Latitude. See *Film latitude.*

Laue method. A method of *x-ray diffraction* using heterogeneous x-rays and a stationary crystal.

Lead equivalent. A lead thickness that *attenuates* the beam the same amount as the material to be radiographed.

Lead foil screen. Different thicknesses of lead foil placed around radiographic film in a cassette to intensify radiation reaching the film and reduce *scattered radiation.*

Lead rubber. A masking material composed of lead oxide evenly distributed in a plastic or rubber envelope; used to restrict the primary beam to subject contour or to mask radiographic film.

Leakage radiation. Radiation penetrating protective barriers.

Leakage test. Carefully monitored surveys of rate of exposure from *leakage radiation* in a *controlled area;* scheduled regularly in *health physics* program.

Level determination. In *tomography,* fixing the exact location of the *fulcrum.*

Light beam. The visible light emitted from a *collimator* that shows the size of the entrance beam at the *subject.* The exit beam will have significantly larger area than the entrance area shown by the light beam.

ight lock. A passage in or out of a processing room that does not allow light into the room; consisting of a revolving door, a maze, or double doors at right angles.

ine-focus. A principle of *anode* construction causing a beam of smaller area, but greater intensity to reach the film than hit the target originally. See *Effective focal area.*

inear accelerator. A device used to increase energy levels of charged particles by varying potentials along a straight line as the particles pass by. See *Accelerator, Cyclotron.*

inear energy transfer. The energy lost per unit length of the path of ionizing radiation through a biological material.

ine voltage. The voltage entering an x-ray generator.

ine voltage compensator. A device designed to assure constant power adjusting the line voltage while the x-ray generator is producing the primary beam.

ocalization. A method of determining depth of a subject within a radiographed object by *stereoradiography,* or *parallax effect.*

ow voltage. The energy range from 50 to 120 kV.

Luminescence. A general term for light emission from biological chemical, or *radiation* sources.

Lymphangiography. Radiography of lymph glands, lymphatics, and lymph vessels. Usually incorporates fluoroscopic *spot film* enlargement or *fractional-focus tube* techniques.

Magnification factor. Magnification factor $= \frac{\text{image size.}}{\text{object size.}}$

Magnification radiography. See *Enlargement.*

Mammography. 1. Radiography of the breast.
2. A generic term for radiographic techniques used with so tissue of poor subject contrast.

Manifest image. The permanent, visible image produced afte developing the *latent image.*

Manipulator. A mechanical device used to turn, hold, or positio a subject. It is usually used inside a cabinet x-ray system an allows external control during fluoroscopic examination.

Manual processing. Developing, fixing, and washing film by han in a dark room, in a series of tanks with separate solution or under ordinary room light by changing solutions in a sing light-tight tank.

Mask. 1. A *radiopaque* material, usually lead, placed around th subject to reduce *scattered radiation.*
2. In *subtraction*, the reverse density copy of the *base film.*

Maximum permissible dose (MPD). The maximum *dose* radiation allowed by regulation to be given to any subje per unit time.

Maze. See *Light lock.*

Mega (M). Prefix meaning 10^6.

Megavoltage. The energy range above 1 MV.

Metallic shot. Small shot pellets, usually lead, poured around regularly shaped subjects for *masking.*

Micro (μ). Prefix meaning 10^{-6}.

Microradiography. Radiography of thin specimens with low x-r absorption, using low kV; usually accompanied with phot graphic image enlargement.

Milli (m). Prefix meaning 10^{-3}.

Milliampere (mA). An electrical current of 0.001 *ampere.*

Milliampere-second (mAs). An exposure value obtained by multiplying the tube current (*mA*) by the exposure time (seconds). Any combination of the two factors giving the same product will reproduce the same exposure value (assuming no other changes). See *Reciprocity law.*

Mirror viewer. A series of lead mirrors used to transmit the image in *fluoroscopy* that permits direct viewing of the radiographic image without exposing the viewer to radiation. See *image distributor.*

Moire pattern. An undesirable pattern on the film resulting from superimposing two stationary grids with the grid lines all running in the same direction. See *Cross-hatch grid.*

Molybdenum (Mo). A naturally occurring element used in *focusing cups, rotating anodes,* and spiral supporting *filaments.*

Monitor. A device that determines the amount of ionizing radiation present.

Monoenergetic beam. Radiation beam of one energy. See *Characteristic radiation.*

Mottle. A spotted appearance on film exposed with *intensifying screens* because of random exposure by photon groups hitting the screen.

Moving grid. ICRU terminology for a *Potter-Bucky diaphragm.*

Multiple film exposure. A technique of exposing several different film types simultaneously on the same subject. It is particularly useful when radiographing a subject with variable densities or thickness.

Multitomography. See *Plesiotomography.*

Myelography. Radiography of the spinal canal exposed to *contrast media.*

N-unit. The amount of measurable *neutron* radiation that will produce the same amount of *ionization* as one *roentgen* of *x-radiation.*

Nano (n). A prefix meaning 10^{-9}.

Natural radionuclide. A member of any parent family (thorium, uranium, or actinium) that decays naturally at a spontaneous, fixed rate.

NCRP. National Council on Radiation Protection and Measurements.

Net density. See *Emulsion fog.*

Net fog. See *Emulsion fog.*

Neutron. An uncharged elementary nuclear particle.

Neutron radiography. *Radiography* by differential *neutron* absorption. To produce an image, a neutron source must be use with radiographic film to form a latent image.

Noise. Any *radiation* other than direct primary radiation causin exposure of film. See *Scattered radiation*, *Fog*, and *Quantu mottle.*

Nomogram. In radiographic exposure charts, a graphic represe tation enabling a dependent variable to be found by connectin the known values of two or more independent variables wit a straight line.

Nondestructive testing (NDT). Any method of detecting co cealed structures in a subject without damaging the subject.

Nonscreen film. Radiographic film relying on direct radiation f image production; designed for use without *intensifying screen*

Notch coding. A means of identifying film types in the dark b the design and number of notches cut into the film.

Nuclide. An atom of any element with a specific number of nuclear *protons* and *neutrons;* not synonymous with *isotope* which are different nuclides of one particular element.

Object. An entity being radiographed. See *Subject.*

Object-film distance (OFD). Distance between an *object* an the *film plane.*

Objective plane. In *tomography*, the plane produced at the *fu crum level*, stationary relative to the *film plane.*

Object shift. In *stereoradiography*, the *tube* is usually shifted la erally while the *object* remains fixed and the resulting pair images is viewed stereoscopically. However, it is also possib to fix the tube and shift the object to produce the stereoradi graph. See *Tube shift.*

Off-focus radiation. Radiation produced by electrons hitting metal surface on the *anode* other than the *target*. The resultin radiation exits the tube at varying angles and is of no us without *collimation.*

Ohm. Unit of electrical resistance. Resistance against one *amper* of current at a potential of one *volt.*

Orthicon camera tube. A type of television camera tube used for closed circuit image viewing in radiography. It requires only low-light levels and produces fine *resolution.*

Orthogonal projection radiography. A form of *in-motion radiography* where an irregularly shaped subject is slowly moved under a fixed source which exposes the film through a slit.

Orthovoltage. The electrical energy range from 160 to 500 kV.

Overcollimation. Excessive restriction of an x-ray beam by lead shutters with a *collimator.*

Overlay. A transparent aid placed on top of a *characteristic curve* which allows direct reading of interpolated values from the characteristic curve.

Packaging. Types of film available commercially, such as sheet film, roll film, or enveloped film.

Pair production. The conversion of energy to mass as a result of an accelerated *photon* (at least 1.02 *MeV* energy) striking a *nucleus*, producing an *electron* and a *positron*. The positron subsequently undergoes an *annihilation reaction.*

Pantomography. *Tomography* in which a panoramic image is obtained by using *slit scanning* with a narrow beam.

Paper radiography. A technique using rapid processing, image-forming, and photosensitive paper for convenience and mobility. The image must be fixed for permanent storage.

Parallax effect. Displacement or enlargement of an image on film as a result of the geometry of the radiation.

Parallel grid. A grid with all its lead strips parallel to each other which results in high *grid cutoff.*

Particle. A minute unit of matter with a measurable mass. See *Alpha particle, Beta particle.*

Pass box. A double-doored light-tight cabinet connecting two rooms through a common wall for the purpose of passing film or cassettes.

Peak kilovoltage (kVp). The greatest value of a potential difference in *kV.* In wave-form propagation, the crest value.

Penetrameter. A standard test piece which is radiographed simultaneously with the subject to insure conditions of exposure, film processing, and overall quality. Referred to in Europe as an *image quality indicator.*

Penetration. The ability of x-radiation to penetrate an object without absorption. Penetration is directly proportional to kilo voltage (*kV*).

Penumbra. Area of hazy, unclear *definition* surrounding the edge o an image in a radiograph. See *Umbra.*

Phantom. A piece of material (water, pressed wood, or beeswax that approximates a biological subject in *density* and is used t determine radiation *penetration* and *scatter* before exposin the subject.

Phosphorescence. The ability of certain substances to continu emitting visible light after exposure to x-radiation is discontinued

Phosphor. A fluorescent material used in crystal form to mak *intensifying screens.*

Photoelectric cell. See *Phototube.*

Photoelectric process. Ejection of an *electron* from an *atom* b a *photon.*

Photofluorography. Photography of fluoroscent screen images.

Photometry. A portion of *radiometry* that measures wavelength within the human visual spectrum.

Photomultiplier tube. See *Phototube.*

Photon. A particle with electromagnetic energy that has momentum but no mass or electrical charge. See *Quantum.*

Photoradiograph. A photograph of the image on a radiograph On the resulting print, the dark areas of the radiograph wi be light on the print from the photoradiograph. To produc a print with normal *density* and *contrast* patterns, an inte mediate negative should be made and the photoradiograp printed from it.

Phototimer. A light-sensitive *phototube* activating an electric time and stopping exposure.

Phototube. A light sensitive diode that when excited by light emit electrons from its cathode which are attached to the anode See *Fluorescence, Phosphor, Phototimers.*

Pi line. A straight line *artifact*, so called because it occurs 3.1 times the diameter from the film edge. It is produced durin automatic processing by a deposit on a roller.

Pico (p). Prefix meaning 10^{-12}

Pinhole projection. A practical method of determining the siz of a tube's *focal spot* by making a pinhole in a thin lea sheet placed halfway between the focal spot and film. The image projected on the film will be approximately the focal spot size.

Pting. Erosion of the *target* surface from electron bombardment. Of the common targets, rhenium-molybdenum surfaces are more resistant than tungsten.

Pnck's constant (h). A constant factor used to determine energy (E) or frequency (ν) of a *photon*: $h = E/\nu$ ($h = 6.6256 \times 10^{-27}$ erg-sec).

Pane-film distance. In *tomography*, distance between *object plane* and film. See *Object-film distance.*

Panigraphy. See *Tomography.*

Pesiotomography. Specialized *tomography* using several film or screen combinations separated in a cassette so that several tomographic sections can be exposed simultaneously.

Pumbicon camera tube. A type of television camera tube used for viewing of radiographic images. A type of *vidicon tube* with better resolution and lower light requirement.

Peumoencephalography. Radiography of the ventricle system exposed to *air-contrast.*

Pcket dosimeter. A portable, direct reading *ionization chamber* for personnel protection that gives an immediate reading of exposure to ionizing radiation. See *Dosimeter.*

Plyenergetic beam. Radiation beam of mixed energies.

Prt. The point of entry of an x-ray beam.

Psitive recall video tape system. An electronic keying device which stores video tape in a central location and can locate and project a specific image on demand from a remote location.

Psitron. A positive *electron*. A product of *pair production.*

Ptential difference. See *Electromotive force.*

Ptter-Bucky. *ICRU* terminology for the mechanism that activates the *grid* in a *Potter-Bucky diaphragm.*

Ptter-Bucky diaphragm. A *grid* that is moved during exposure. The movement blurs out the images of the grid's lead strips on the film, eliminating *artifacts.*

Peservative. An inorganic chemical, sodium sulfite, used in *developer* to protect organic agents from natural oxidation.

Pimary radiation. X-rays emitted from the anode *target* consisting of *Bremsstrahlung* and *characteristic radiation.*

Print. The manifest image produced on photographic paper a exposing the negative and photographic paper to light a *processing.*

Print-out image. Darkening of film from exposure to light. S *Base density.*

Processing. The chemical process of converting a *latent image* film into a permanently visible image.

Projection. The relative attitude of the *subject* to the film.

Protection. See *Health physics.*

Protective barrier. See *Barrier.*

Proton. An elementary, positively charged particle found in nuclei.

Pulse. An electrical signal generated by a single event of ioniz radiation.

Pulse amplifier. An instrument designed to amplify relatively we or intermittent signals of radiation detection equipment.

Purple discoloration. Change of coloration of glass in x-ray tub an effect of x-radiation or Beta rays on glass.

Quantum. A unit of energy equal to the product of the frequen of radiation (u) and *Planck's constant* (h). Quantum = A *photon* carries a quantum of electromagnetic energy.

Quantum mottle. A mottled film appearance caused by the acti of x-ray *quanta* striking *fast film* and *screen* combinatio See *Mottle.*

Quantum theory. A theory proposed by Planck that energy not emitted or absorbed continuously, but is intermitten radiated in units of definite magnitude called *quanta.*

R-meter. An instrument designed to measure radiation *dose.*

Rad. Unit of *absorbed dose* of ionizing radiation (acronym **r**adiation **a**bsorbed **d**ose). 1 rad = 100 ergs/gram.

Radiation. Emission of energy through matter or space in eith waveform or particle form.

Radioactivity. Emission of ionizing radiation from unstable *clides* undergoing spontaneous decay.

Radioautography. See *Autoradiography.*

Radiobiology. The study of the effects of *radiation* on biolo cal systems.

adiograph. The image produced on film as a result of exposure to x-radiation. See *Processing*, *Latent image*.

adiographic contrast. The overall *contrast* on the radiographic image resulting from difference in density of the subject and the film.

adiography. The study and application of x-radiation and its application to image production.

adiology. The study and application of radiation (including x-rays and radionuclides).

adiolucent. Allowing transmission in whole or part of x-radiation through a subject. See *Contrast agent*, *Radiopaque*.

adiometry. The study of measuring radiant energy of ultraviolet, visible, and infrared radiation.

adiomimetic. Chemical reactions causing biological effects similar to those caused by ionizing radiation. See *Erythema*.

adionuclide. A radioactive *nuclide*.

adiopaque. Not allowing transmission of x-radiation through a subject. See *Contrast agent*, *Radiolucent*.

ay. A beam of energy.

eciprocity law. In *radiography*, the product of tube current (mA) and exposure (seconds) equals a constant (mAs).

ectification. The process of changing *alternating current* to *direct current*.

eflection microradiography. See *Electron emission radiography*.

elative Biological effectiveness (RBE). A factor used to compare the effectiveness of *absorbed doses* of different types of ionizing radiation on a biological system. See *Rad*, *Rem*.

elaxation. In *xerography*, the process of cleaning and heating the aluminum plate for reuse after exposure. Improper relaxation results in incomplete image removal and possible double exposure.

em. Unit of dose equivalent (acronym for **r**oentgen **e**quivalent **m**an). For x-radiation, 1 rem = 1 rad = 1 roentgen.

emnant radiation. Radiation that passes through the subject and strikes the film.

eplenishment. Adding volume or adjusting concentration of processing chemicals to compensate for use and evaporation.

Resolution. The minimum distance between two image *subje* that may be distinguished on the film, monitor, or fluoroscop

Restrainer. A chemical, usually potassium bromide, which reduc *fogging* by allowing the developer to act on exposed (but r unexposed) silver grains in film emulsion.

Retarded asymmetry. In *tomography*, an asymmetrical exposu near the end of the *tube-film trajectory*.

Reticulation. Netlike pattern in film emulsion caused by extre temperature changes during *processing*.

Reverse-density. Transposing *densities* in a contact print ma from a radiograph. See *Mask*.

Rinsing. Process of exposing film to a running water rinse th minimizes contamination in processing solutions and reduc risk of streaking dried film with fixer residue.

Rod-anode tube. See *End-grounded tube*.

Roentgen (R). Unit of exposure. 1 R $= 2.58 \times 10^{-4}$ coulomb ions/kilogram of air under standard conditions. Named Wilhelm Konrad Roentgen, German physicist credited with d covering x-rays in 1895.

Roentgenography. See *Radiography*.

Roentgenology. See *Radiology*.

Roentgenoscopy. See *Fluoroscopy*.

Roentgen rays. See *X-rays*.

Roll processing. A form of manual processing whereby film i rolled onto a reel and placed inside a light-tight contain Processing solutions are poured into and out of the contai through the cover.

Rotary radiography. A form of *in-motion radiography* where a st film is placed around the circumference of a cylindrical subje covered with a lead mask and exposed through a slit as t subject and film rotate.

Rotating anode. A rotating *target* in x-ray tubes composed o disc of rhenium-tungsten alloy on a molybdenum body whi rotates at 3300 rpm (or triple speed at 10,000 rpm).

Safelight. A light providing visibility during the dark phases processing. The light wavelength is selected according to t sensitivity of the film being exposed, or processed.

Scanner. A video recording system which allows image stora of a single x-ray image from *fluoroscopy*.

Scanning disc. A piece of lead with apertures of various sizes placed in front of the *Bucky* or *grid*, used with early *phototimers*.

Scattered radiation. Radiation which has interacted with atoms, changing the direction of the photons. See *Backscatter*.

Scholz tunnel. An early fluoroscopic spot film device named for its innovator, Frank Scholz.

Scintillation. Light produced when a photon strikes *phosphor* crystal. See *Fluorescence*.

Scout. In *tomography*, a test exposure to determine the correct *objective plane*.

Screen. See *Intensifying screen*.

Screen contact. The space between *screen* and film must be as small as is practical to keep photon excitation from the screen from producing blurred film images.

Screen film. Radiographic film used with *intensifying screens*.

Screen lag. Continuing phosphorescence of *fluoroscopic* and *intensifying screens* after removing the source. Fluoroscopic lag is considerably stronger than that of intensifying screens.

Second-order subtraction. Preparing two *masks* from the *base film* during subtraction. The second mask is usually prepared to overlay a poorly exposed first mask.

Secondary radiation. Radiation emitted after interaction of x-radiation with atoms. See *Primary radiation*.

Section. In *tomography*, the plane of exposure. A section's thickness is determined by the amplitude of the tube travel.

Self absorption. Absorption of radiation within the subject radiographed.

Sensitivity. See *Film speed*.

Sensitometric curve. See *Characteristic curve*.

Sensitometry. A method of quality control for image standardization. See *Characteristic curve*.

Shape distortion. A misrepresentation of the object shape caused by improper alignment of *tube*, *object*, and *film*.

Sharpness. See *Definition*.

Shield. See *Barrier*.

Short stop. See *Stop bath*.

Shoulder. That portion of the slope on a *characteristic curve* representing film images of high *densities* and low *contrasts*.

Shutter. A lead projection inside a collimator used to adjust o strict the size of an x-ray field or to stop the radiation comple Many collimators have automatic shutter adjustments to c pensate for beam restriction as *focus-film distance* varies.

Side scatter. Scattered radiation produced by photons striking interacting with walls adjacent to the subject.

Silver bromide. The light sensitive chemical in film emulsion wh when excited by photons produces a *latent image* tha made visible by immersing the film in a solution of si nitrate and potassium in total darkness.

Single-coated film. Radiographic film with an emulsion layer one side only.

Size distortion. A misrepresentation of the object size cau by divergence of the x-ray beam when the *object-film dista* is short.

Slit scanning. A radiographic technique to shield the entire *ob* from excessive x-radiation. The primary beam passes throu a lead slit exposing only the *subject*. A disadvantage is t the lead shielding must be heavy enough to absorb all radiat except that passing through the slit.

Soft tissue radiography. See *Mammography.*

Soft x-rays. A beam of relatively low energy and long waveleng produced by low generating kV.

Solid state rectifier. A consolidation of individual *diodes* co nected in series and insulated; usually made of silicon. Th have a very low voltage drop as compared with *valve tu rectifiers* and do not need a heated *filament*.

Source. The *focal spot* on the *anode* where the primary bea originates.

Source-film distance (SFD). See *Focus-film distance.*

Space charge. The result of *thermionic emission* from an candescent filament. See *Thermion.*

Spectral distribution curve. A plot of an x-ray beam's wav length and photon energy. See *Spectrum.*

Spectral window. A combination of *target* and *filter* made of t same metal, usually molybdenum, in which the filter transm the *characteristic radiation* emitted by the target.

Spectrum. A representation of the distribution of radiation inte sities, usually expressed in terms of wavelength, energy, frequency.

Speed. See *Film speed.*

Speed factor. See *Intensifying factor.*

Spinning top. A device used to check the accuracy of radiographic timers. A lead top with a single hole drilled through its periphery is spun on film during an exposure and the number of holes shown on the film is related to the accuracy of the timing device.

Spot film. A technique used to obtain a still radiograph during *fluoroscopy.* See *Scanner.*

Stable. Not *radioactive.*

Stanford stereoscope. A large *stereoscope* using prisms and mirrors for viewing *stereoradiographs.*

Static marks. Circular or tree-like black artifacts on radiographic film caused by static electrical discharge when handling film in dry atmosphere. These may be avoided by removing film from cassette or envelope gently.

Stationary grid. A non-moving *grid* whose disadvantage is that its lead strips may appear as images or shadows on the processed film. See *Bucky grid.*

Stem radiation. See *Off-focus radiation.*

Stereoradiography. Technique of producing radiographs that are viewed in three dimensions.

Stereoscope. An optical instrument allowing three dimensional viewing of stereo images.

Stereoscopy. Viewing objects in three dimensions.

Stop bath. An acetic acid solution that stops the developing process of film chemically. A two minute rinse in running water may be substituted for it.

Stratigraphy. See *Tomography.*

Stray radiation. The sum of off-focus and *scattered radiation* reaching the subject.

Streaming. Increased transmission of x-rays through a less dense area of the subject.

Strip film camera. A serial camera capable of taking *spot films* rapidly (1-5 frames/sec) and directly from the *phosphor* output of an *image intensifier.*

Subject. That part of an *object* being radiographed that is the point of interest.

Subject contrast. The portion of radiographic *contrast* attribut to differential absorption and transmission of x-rays through t subject. See *Streaming.*

Subtraction. A photographic technique used to clarify radiograp interpretation. After radiographing the subject, a *contrast me ium* is introduced into the subject and a second radiogra is prepared. The first radiograph (the *base film*) is exposed wi subtraction film to produce a reverse-density image (the mas The mask is superimposed over the second film with the contra agent in the subject. All images except the ones with th contrast agent are eliminated from the two superimposed film leaving the subject for easy interpretation.

Supervoltage. See *Megavoltage.*

Survey meter. A portable radiation detection instrument.

Tank processing. A method of processing film manually in series of tanks containing the different processing solutions.

Target. The surface area on the *anode* which is struck by fre electrons emitted from the *filament.*

Target angle. The degree of bevel on the *anode* face; usual about 18°.

Teleradiography. A radiographic procedure that minimizes disto tion by using parallel rays and a *focus-film distance* of at lea six feet.

Tera (T). Prefix meaning 10^{12}.

Thermion. An electron liberated by heating an *electrode.* Se *Space charge.*

Thermionic emission. The liberation of *thermions* from a conductor by an electric current.

Thermionic tube. Tube that produces electrons by heating an *electrode.*

Thoraeus filter. A filter of tin, copper, and aluminum (in tha order from tube to object) allowing the *half value layer* o copper and aluminum but with less beam *attenuation.*

Thoriated. A cathode filament impregnated with thorium oxide (ThO_2) to increase *thermionic emission.*

Timer. See *Electron impulse timer, Electronic timer, Phototimer.*

Time-temperature. The manufacturer's recommended developing time and temperature combination for processing film. Standard time-temperature for manual developing is five minutes at 20° C (68° F).

omogram. A radiograph produced by a *tomograph.*

omograph. The instrument used in *tomography.*

omographic angle. The angle produced by amplitude of the *fulcrum.* The larger the tomographic angle, the thinner the section. See *Tomography.*

omographic section. In *tomography,* the radiograph of the *objective plane.*

omography. A radiographic procedure that makes an image of a single plane in the subject. The plane is chosen by making it the *fulcrum level* between the x-ray tube travelling in one direction and the *film plane* travelling in the opposite direction. All planes above and below the fulcrum are blurred out of focus on the film. The synchronous tube-film motion may be linear, circular, or hypocycloidal.

omoscopy. A technique coupling *tomography* with an *image intensifer* for specifically locating a *subject.*

oner. In *xerography,* a negatively charged powder (calcium carbonate) that is sprayed on the positively charged aluminum plate, producing the manifest image.

otal filtration. The sum of *inherent filtration* plus added filtration.

riode. See *Grid-controlled x-ray tube.*

ube. The device which generates x-rays. A *filament* heated by an electric current (*cathode*) produces electrons which are propelled by a high voltage source toward the *target* on the *anode.* All components are surrounded by an evacuated glass *envelope.*

ube current. Current passing between the *cathode* and *anode* during x-ray generation; measured in milliamperes.

ube-film trajectory. In *tomography,* the synchronously opposing paths of the tube and film.

ube rating. The manufacturer's specified heat-loading capacity of an x-ray tube.

ube shift. The actual lateral distance necessary to shift the x-ray tube when producing a *stereoradiograph.* Generally, tube shift/focus-film distance = 1/10.

ube side. That side of a subject, film holder, *cassette,* or *grid* which must face the tube *focal spot.*

ungsten. The metal usually used in the *filament* coil of *cathodes* and the *target* surface of *anodes* in x-ray tubes becaus its high atomic number, high melting point, high ther conductivity, and low vapor pressure at high temperatures.

Ultrasonic testing. Transmitting high frequency sound wa through a *subject* as a method of *nondestructive testing.*

Umbra. The image proper on a *radiograph.* See *Penumbra.*

Undercut. Shadow formation in a subject of variable thickn caused by scattered radiation from a thinner portion creat a darker border near the thicker portion. See *Scattered ra ation.*

Unmodified scattering. See *Coherent scattering.*

Unsharpness. Lack of *definition*, low *acutance* in an image caus by improperly aligned geometry. See *Penumbra.*

Unstable. *Radioactive.*

Urography. Radiography of the kidney and urinary system.

Use factor (U). That part of the energy used to introdu *primary radiation* to the *subject.*

Useful beam. See *Primary radiation.*

Vacuum cassette. A special film cassette which can be evacuat to assure better screen-film contact.

Vacuum diode rectifier. See *Valve tube rectifier.*

Valve tube rectifier. A *diode*, vacuum tube which permits elect flow in only one direction, used in circuits to rectify curren They do not produce x-rays unless a sufficient voltage dr occurs.

Venography. Radiography of veins using *contrast media.*

Ventriculography. Radiography of the skull ventricles exposed air as a *contrast medium.*

Video disc scanner. See *Scanner.*

Video system. Electronically coupling the fluoroscope with a tel vision camera and monitor, *video tape system*, or *video di scanner.*

Video tape system. In *fluoroscopy*, a video tape recording wi the advantage of showing images immediately, without proces ing. It also requires less radiation exposure than *cineradiograph*

Vidicon camera tube. A type of television camera tube use for image viewing in radiography. It is relatively inexpensi but requires bright light levels for operation.

Viewing room. A room with variable light intensity and equipped with illuminators for inspecting radiographs.

Volt. Potential difference allowing a current of one *ampere* to pass a resistance of one ohm.

Voltage compensator. An instrument used to adjust and control voltage to an x-ray source.

Wafer grid. Any laminated materials alternating *radiopaque* and *radiolucent* layers to reduce *secondary radiation*.

Washing. An intermediate processing step using running water to remove excessive chemicals from the film. The minimum washing time is 20 minutes at 20° C.

Water marks. Spots left on a dried film caused by water drops adhering to the film after washing. As the film dries, the areas under the drops dry slower than the remainder of the film resulting in gelatin distortion. Water marks may be avoided by using *wetting agents*.

Watt. An electrical unit of work per unit of time. Wattage — amperage × voltage; 746 watts = 1 horsepower.

Wavelength. The distance between two successive crests in a wave propagation; ordinarily, the practical range of x-ray wavelengths are between 0.1 and 0.5 Å.

Wave theory of radiation. A theory that explains the movement of x-rays as electromagnetic waves traveling at the speed of sound and bearing no electrical charge.

Wet reading. Viewing the exposed radiograph before completed processing, such as during fixing or washing.

Wetting agent. A surface tension reducing solution applied after washing film to reduce *drying* time and prevent *water marks*.

Wheatstone stereoscope. A large *stereoscope* using prisms and mirrors for viewing *stereoradiographs*.

Wiremesh test. A simple test of screen-film contact. A 1/4" wire mesh is placed in direct contact with screen-film (cassette) and radiographed. The image is then checked for sharpness. Poor screen-film contact results in a blurring of the wiremesh image.

White radiation. See *Bremsstrahlung*.

Workload. The amount an x-ray generator is used, expressed in mA minutes/week or in R/week.

Xerography. An image-forming process in which photons exc selenium crystals on a positively charged aluminum plate. latent image is formed on the plate (the charge and seleniu excitation are proportional to the subject's absorption of ph tons), which is made visible by spraying a negatively charg powder (*toner*) on the plate The plate is then *relaxed* heating and cleaned for reuse.

Xeroradiography. Xerography in which x-radiation is used to exci the selenium crystals. See *Xerography.*

X-ray. A penetrating form of electromagnetic radiation with sho but variable wavelengths, traveling at the speed of light. X-ra are generated within an x-ray tube by fast moving electro suddenly changing velocity.

X-ray crystallography. See *X-ray diffraction.*

X-ray diffraction. Measuring and identifying crystalline structure the image diffraction of *monoenergetic photons* colliding wi characteristic atomic planes in the crystal.

X-ray machine. See *X-ray system.*

X-ray protection. See *Health physics.*

X-ray quality. Penetrating power of an x-ray beam. A high quali photon beam has high energy, high frequency, and short wav length.

X-ray quantity. The amount of exposure to ionizing x-radiatio measured in air in units of *roentgen.*

X-ray spectroscopy. Technique of representing energy or wav length emission spectra of elements bombarded with x-ray The x-ray emitted from the element (*characteristic radiatio* is measured with a spectrometer.

X-ray system. The total assembly used to produce x-radiatio including generator, controls, shielding and power.

X-ray tube. See *Tube.*

Yttrium oxysulfide. See *Gadolinium oxysulfide.*

Zinc cadmium sulfide. A *phosphor* used in fluoroscopic screen that emits a green light and has little or no phosphorescence.

Zonogram. Radiograph produced using *zonography.*

Zonography. A type of *tomography* using a *tomographic angle* c 5° to 10° that produces a relatively thick *section* (abou 10 mm), but with good contrast.

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Dear Cochairmen:

We are pleased to send you the National Program and Southern Regional Plan of Research for Forests and Associated Rangelands. These programs were developed as a joint effort between the U.S. Forest Service, SEA-CR, and the forestry schools.

Through regional and national conferences, we obtained suggestions from governmental, industrial, consumer, environmental, and conservation organizations having an interest in forestry research. These programs reflect the advice given to us by those organizations.

This planning effort is directed toward several objectives. First, to guide forestry research planning in the Science and Education Administration and the participating forestry schools. Second, to provide the basis for the research portion of the 1980-85 Forest Service program required by the Resources Planning Act. And third, to provide a reference base for future planning.

Sincerely,

R.G. Merrifield

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Enclosure

FOREWORD

This research plan for the Southern Region is a companion publication to the National Program of Research for Forests and Associated Rangelands. While the national program reflects both regional and national priorities, this plan provides details on forestry research matters concerning the South. For the reader's convenience, background information on development of this regional-national planning effort is also presented.

Although this is not the first coordinated effort to plan forestry research in the South, it is unprecedented in the extent to which research needs have been identified by a broad cross section of public land management agencies, industries, environmental and citizen groups, and professional organizations.

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THE PLANNING PROCESS

On July 16, 1976, the Agricultural Research Policy Advisory Committee, a joint committee of the U.S. Department of Agriculture and the National Association of State Universities and Land Grant Colleges, requested its member organizations to prepare a National Program of Research for Forests and Associated Rangelands. The Deputy Chief for Research, U.S. Forest Service, and the President of the Association of State College and University Forestry Research Organizations were designated cochairmen of a steering committee for this effort. The Regional Director, North Central Region, State Agricultural Experiment Station Directors, and the Deputy Administrator, Cooperative State Research Service, USDA, were appointed members of the committee.

Long-range planning of forestry research on a coordinated basis is not new to the South. Actually, development of this regional plan extends efforts begun in 1972 within the framework of the Regional and National Agricultural Research Planning System—an iterative planning process to identify and solve local, regional, and national problems affecting agriculture and forestry. This planning system is headed by a national committee that coordinates activities of four regional planning committees Northeastern, North Central, Southern, and Western. It operates continuously, projectin new 5-year research efforts every two years.

The Research Program Gro on Forest Resources (RPG-2) was established by the Southe Regional Planning Committe in 1972 to aid development a continuous evaluation of forestry research in the South. In 1974, all Research Program (RP's) were thoroughly evaluated by six task forces compo of scientists with the disciplin knowledge needed to identify principal needs. Reports of th task forces, which were distri uted to research administrato and scientists throughout the South, provided much background for the current plannin effort.

In planning the developme of a National Program of Research for Forests and Associa Rangelands, the National Stee ing Committee determined th two major facets of the progr required study—its conduct a its content. Program *conduct* was studied at the national le during a three-day Forest and Rangelands Symposium. The

ort, "A Review of Forest and
geland Research Policies
ne United States," was pub-
ed in 1977 under sponsorship
he Renewable Natural
ources Foundation.
o examine the *content* of the
gram, cochairmen of the four
onal Research Planning
ups held regional working
ferences to get opinions on
arch needs from a broad
trum of public and private
sumer and user groups. Later,
tional working conference
ught together results of
policy study on program
duct and the four regional
erences on *content* to pro-
perspective to the entire
ning effort. This approach
onded to the Forest and
geland Renewable Resources
of 1974, which requires
stry research planning to
continual process, with
le opportunity for public
icipation.
ith direction from the
ional Steering Committee,
onal working conferences
held in Philadelphia,
neapolis, New Orleans, and
Francisco during July 1977.
eparation for these confer-
es, a National Reference
ument was prepared by a
task force of the U.S. Department of Agriculture and National Association of State Universities and Land Grant Colleges. Its purpose was to provide attendees to the working conferences with background information on the overall scope of forest and rangeland research, including past accomplishments, current programs, and research administrators' suggestions for emphasis in 1980 and 1985. At the same time, a Southern Regional Reference Document was published as a companion to the national document. It provided scientist and research administrator views of emerging research needs specific to the South, and projected research efforts in terms of scientist years (SY's) for 1980 and 1985.

This research plan for the Southern Region is based in part on results of the working conference held in New Orleans, Louisiana, on July 27-28, 1977. About 120 representatives of public and private consumer and user groups in the South attended the conference and identified a total of 533 problems.

In December 1977, seven task forces composed of university and Forest Service research scientists evaluated the conference results. Each task force consisted of six to nine persons representing disciplines within the subject areas of concern. Evaluation consisted of examining problem classification by subject area, determining whether or not problems were researchable, and rating their relative importance, considering user needs together with scientific opportunity and likelihood of successful solution. The final step involved redistribution of the 1980 and 1985 SY projections contained in the Southern Regional Reference Document to reflect both user needs and scientific opportunities. Thus, the scientist task forces played a critical role in the planning effort by melding the concerns of users and scientists into a workable research plan.

Final projections and plans reported in this document were developed by Forest Service and university representatives. The plan is based on results from the Southern Regional Working Conference, together with the scientist task force evaluation. Consideration was also given to results of the National Conference and the subsequent assessment by the scientist task forces.

ROLE OF THE SOUTH

When forestry leaders speak of meeting wood product demands in 1985 and beyond, all eyes turn southward. The soil, climate, and topography of the South combine to form near ideal conditions for the growth and harvesting of trees. So much so that southern forests are expected to produce half the Nation's wood products needs by the year 2000, while providing livestock forage, clean water, wildlife habitat, and recreational opportunities.

A writer once said that the South's true fascination lies not in its rich heritage but in its dramatic potential. This holds doubly true for its forests. The most recent national timber review found that southern timberlands were producing 30 percent more pine sawtimber than was being harvested, yet the average acre of forest land in the South is capable of growing two to three times more timber than at present. While over 60 million acres of forested rangelands are now providing forage for cattle, production from such lands can be increased greatly by using management guidelines developed by research. Populations of many wildlife species and opportunities for recreation in the South can be increased through new forest management techniques.

This potential offers a unique challenge to forestry research, because most of the gain in forest goods and services must come from small, nonindustrial ownerships that control 72 percent of the forest land. And the key to meeting the South's goals lies in more intensive management and better utilization practices. Developing ways of achieving these two objectives would be challenging enough, but research also must foresee and provide acceptable solutions to attendant problems that arise. For example, insects and diseases will become more important as intensive management increases. Wildfires will become more costly as forest investments rise and plantations of genetically improved trees are established. Soil productivity and water quality will gain higher priorities for future research, as will impacts for wildlife and recreation usage.

While considerable resear
attention will still be given t
pine forests, overall land ma
agement and production go
cannot be met without an a
vancement in hardwood silv
culture and utilization. This
includes bottomland hardw
that are decreasing in quant
each year due to agricultura
encroachments, and low-gra
hardwoods on sites where p
would be more productive.
Rehabilitation of degraded
land and mountain forests w
be necessary to meet deman
for large, high-value hardw
now in short supply. Too, ut
tion of small, low-grade har
woods must be improved to
supplement burgeoning dem
on softwoods, and permi
foresting depleted stands wi
more desirable species.

Forestry research in the S
encompasses all this and mu
more. To a very great extent
success of future research in
tributing to forestry progres
will depend upon the priorit
and directions decided upon
right now.

RESENT AND PROJECTED ORESTRY RESEARCH EFFORT

The University-Forest Service
search effort in the Southern
gion is outlined here for the
se year 1975, with projections
r 1980 and 1985, in terms of
entist years (SY's) of research
rk. As shown by the accom-
nying table, plans call for
creasing the effort 36 percent
1980, and 59 percent by 1985.
further breakdown of these
ta, showing present and pro-
ted SY's for universities and
Forest Service separately,
pears in the Appendix.

Information is presented on current program emphasis, and priorities are listed for continuing and new research. These priorities represent the research needs identified and rated during the regional working conference and evaluated by the scientist task forces. Many of these priority research needs were highlighted in the six 1974 Task Force Reports, prepared under the guidance of the Research Program Group on Forest Resources (RPG-2).

Present and Projected Forestry Research in Southern Region by Research Program: 1975, 1980, and 1985

	Scientist Years			
Research Program	1975	1980	1985	Increase 1975-1985
Multi-resource Inventory, Appraisal, and Evaluation	29	58	59	30
Timber Management	145	179	195	50
Forest Protection	92	94	95	3
Harvesting, Processing, and Marketing of Wood Products	58	80	89	31
Forest Watersheds, Soils, and Pollution	32	64	87	55
Forest Range, Wildlife, and Fisheries Habitat Development	20	41	62	42
Forest Recreation and Environmental Values	15	15	35	20
Total	391	531	622	231

MULTI-RESOURCE INVENTORY, APPRAISAL, AND EVALUATION

Inventory is vital to any business, and forestry is no exception. To meet future demands for forest goods and services from the South's 200 million acres of forest land, we must keep a constant check on supply of resources available. Predictions of future demands must be based on reliable data that reflect the ever-changing mood and tempo of the nation. Ownership patterns must be monitored continually, for management objectives differ widely among various ownerships. And, because the forest land base is decreasing each year, better ways to accommodate multiple uses in conjunction with increased timber production on available acreage are imperative.

	Scientist Years		
	1975	1980	1985
Multi-resource Inventory and Appraisal	22	45	45
Alternative Uses of Land	1	3	3
Multiple-Use Potential and Evaluation	6	10	11
Total	29	58	59

ulti-Resource Inventory nd Appraisal

Current Program Emphasis

- tatus and trends of the timber ources of each southern state. is is determined in statewide veys every 10 years, with dating for some states at ears.
- tatewide analyses of forest d management opportunities, nership patterns, timber ducts output, and potential expanding the forest-based nomy.
- egional analyses to answer cific questions. For example: ply of utility poles, extent of d clearing for agriculture, l hardwood distribution on r sites.
- asic techniques for collection, pilation, and evaluation of istical data on forage for stock and on wildlife habitat.

Priorities for Continuing and New Research

- *horten Forest Survey cycles up-to-date information on ortant changes in resource*
- *Develop methods to define commercial forest land so inventory data show actual availability of timber, game, and other resources.*
- *Develop methods to inventory ecosystems, their biological components, and the physical environment.*
- *Provide ground control techniques to facilitate high-altitude remote sensing for multi-resource evaluation.*
- *Improve the availability and usefulness of multiple resource data.*

Alternative Uses of Land

Current Program Emphasis

- *Economic feasibility of combining timber production with other land uses such as forage production for livestock and habitat for wildlife.*
- *Institutional factors affecting land use. These include taxes, ownership patterns, credit sources, government and private assistance programs, laws, and population growth.*
- *Future forest land requirements for uses such as agriculture, highway rights-of-way, and urban and industrial development.*

Priorities for Continuing and New Research

- *Identify the effects of each use of forest land on the long-term productivity of that land.*
- *Develop forest land taxation alternatives to simplify and stabilize forest management.*
- *Compile information to compare forestry returns with alternative uses of land and capital.*
- *Examine owner objectives in relation to owner characteristics, ownership size, tenure, and planning horizon.*
- *Determine economic tradeoffs between intensive timber management practices and production of forest game and forage for livestock.*

MULTI-RESOURCE INVENTORY, APPRAISAL, AND EVALUATION. (Cont.)

Multiple-Use Potential and Evaluation

Current Program Emphasis

- *Effective allocation of cost-sharing funds in forestry incentive programs.*
- *Methods for ranking forestry investments.*
- *Impacts on forest resources of changing land-use patterns.*
- *Ways to maximize returns from forestry investments.*
- *Response of forest owners to public and private forestry assistance programs.*

Priorities for Continuing and New Research

- *Derive management systems for optimum mix of timber, wildlife, recreation, and other benefits.*
- *Evaluate impact of anticipated high demands on the forest resource for energy.*
- *Develop methods for quantifying intangible values for non-marketable forest resource uses and benefits.*
- *Compile cost-benefit data for single resources or multi-resource combinations on small woodlands.*
- *Find new approaches to arbitrating resources allocation issues on public lands.*
- *Define and evaluate alternative public programs directed toward multi-resource management, particularly small ownerships.*

IMBER MANAGEMENT

Obviously, to meet future demands for forest goods nd services and still produce the needed timber supplies, e must increase timber production per acre. In the outh, this translates into the culture of about 70 pine nd hardwood species from forest establishment through arvest to reestablishment. Genetic improvement and conomics are important elements of this program area.

	Scientist Years		
	1975	1980	1985
iology, Culture, and Management of Forests and Timber-Related Crops	95	120	130
enetics and Breeding of Forest Trees	33	32	34
conomics of Timber Production	17	27	31
otal	145	179	195

Biology, Culture, and Management of Forests and Timber-Related Crops

Current Program Emphasis

- *New reforestation methods to insure restocking of harvested areas and reclaim abused land with desired species. For example: use of containerized planting stock, inoculation of seedlings and soils with specific mycorrhizal fungi, and encapsulation of seed for direct seeding.*
- *Influence of site and cultural practices on stand yield and quality.*
- *Methods for integrating other forest land uses with timber production. For example: requirements for maintaining habitats of endangered species such as the red-cockaded woodpecker.*
- *Ways to increase production of timber-related crops. For example: recent studies indicate that oleoresin yields can be increased 50-100 percent with use of genetically improved stock and improved extraction techniques. New research has shown that injections of paraquat and diquat can stimulate production of resin in the living tree.*

- *Data on growth and yield of intensively cultured slash and loblolly pines, including genetically improved strains, by age, site, and stand (plantation) density.*
- *Improved nursery practices for pines and hardwoods, especially genetically improved strains. The objective is to produce uniformly good physiological grades of seedlings with consistently high field survival and rapid early growth.*
- *Improved methods and intensities of site preparation for controlling competing vegetation and establishing desirable species.*
- *Upland, mountain, and bottomland hardwood management guides for use in natural stands and plantations for optimum yield of wood products.*
- *Effects of management practices, including fertilization and site preparation, on soil and site properties. Particular attention is given to long-term productivity under short rotations.*
- *Alternative methods of regenerating and managing natural stands of pine and pine-hardwood types for different landowner objectives.*

Priorities for Continuing and New Research

- *Provide managed stand growth and yield information.*
- *Develop timber management guides for intensive culture of southern pines, including use of fire.*
- *Develop total biomass volume tables by site, species, and diameter.*
- *Provide multi-product growth and yield information for both natural stands and plantations of pines, hardwoods, and mixed species.*
- *Perfect minimum site preparation techniques to protect sites, reduce costs, and achieve desired stocking.*
- *Develop practical methods of regeneration, TSI, thinning, and management for partially stocked stands.*
- *Improve techniques for regenerating and growing natural stands of hardwoods, including those in bottomlands.*

Genetics and Breeding of Forest Trees

Current Program Emphasis

- *Identification of genetic variation and superior traits o more than 15 major hardwoo and softwood species in the South. Much of this is being accomplished by extensive experimental plantings.*
- *Improved sexual and asexua reproduction methods to mass produce seedlings with desirab traits. Through genetic improv ment, growth increases of 10 t 25 percent with southern speci have been obtained. Such resu have encouraged establishmen of nearly 8,000 acres of planta tions for the production of improved seed.*
- *Seed orchard management strategies to insure consistentl higher yields of superior seed.*

Priorities for Continuing an New Research

- *Expand breeding program for fusiform rust resistance.*
- *Develop breeding strategies for advanced generations.*
- *Improve seed technology.*

Breed improved strains of
ks, yellow-poplar, walnut, and
er high-value hardwoods
t show rapid initial growth.

conomics of imber Production

Current Program Emphasis

actors affecting costs and
efits of thinnings—commer-
and noncommercial.

Opportunities and values of
ber stand improvement, with
phasis on cost-sharing with
ners of small, nonindustrial
ests.

conomic effects of converting
lions of acres of land with
-quality hardwood to pine,
response to rising softwood
mands.

ystems to evaluate timber
nagement alternatives based
net income resulting from
rious management levels,
nning regimes, product com-
ations, and rotation lengths.

Priorities for Continuing and New Research

- *Evaluate potential returns for a range of cultural investments in forest management.*
- *Relate yield to varying levels of site preparation to provide best economic prescriptions.*
- *Provide economic analysis of energy demands in forest production.*
- *Investigate economics of multi-product wood production.*
- *Compare industrial and governmental landowner assistance programs for efficiency and effects on resource base.*

FOREST PROTECTION

The southern pine beetle is the major pest in our southern forests. During the past 10 years, this insect has infested more than 40 million acres. But, while the beetle is a major threat, it is by no means the only enemy of southern trees. Other insects, diseases, and wildfire are so menacing that, together, they annually claim more volume of timber than is harvested in any given year.

	Scientist Years		
	1975	1980	1985
Control of Insects Affecting Forests	41	45	45
Control of Diseases, Parasites, and Nematodes Affecting Forests	33	35	35
Prevention and Control of Forest and Range Fires	18	14	15
Total	92	94	95

ontrol of Insects ffecting Forests

Current Program Emphasis

Methods for estimating
rrent population levels and
edicting future levels of south-
n pine beetle activity.

nvestigation of toxicants and
havioral chemicals for con-
lling insect populations.

Relationship of bark beetle
ivity to soil, site, individual
e, and stand factors.

Procedures for monitoring
pacts of cone and seed insects
orchards.

Techniques and strategies that
l protect pine regeneration
m pests during the susceptible
t 2 to 3 years of growth.

mprovement of silvicultural
trols for pine and hardwood
ntation insects (sawflies, tip
ths, defoliators, etc.) and
plementation of existing
ural controls.

ilvicultural practices affect-
hardwood borers such as the
penterworm. Also included
studies of sex attractants,
mical and microbial insecti-
es, and impact assessment.

iological and ecological
tors that contribute to cyclic
oulation outbreaks of hard-
od defoliators such as tent
erpillars.

Priorities for Continuing and New Research

- *Develop techniques to prevent, contain, or suppress southern pine bark beetle outbreaks.*
- *Find ways to control cone and seed insects in southern pine seed orchards.*
- *Improve methods of predicting population dynamics of important forest insect pests.*
- *Develop environmentally acceptable, specific insecticides, and biological control techniques for important forest insect pests.*
- *Assess environmental and economic impacts of important forest insect pests.*

Control of Diseases, Parasites, and Nematodes Affecting Forests

Current Program Emphasis

- *Control of pine nursery and regeneration diseases, which account for 20 to 30 percent of annual seedling losses. Research includes epidemic prediction, chemical controls, and identification of microorganisms and cultural practices for biological control.*
- *Control of fusiform rust—the most important disease of southern pines. Research on this problem has centered on control in the nursery and development of rust-resistant pines.*
- *Control of* Fomes annosus *root rot—the second most important disease of southern pines.*
- *Control of decay fungi in southern hardwoods.*
- *Causes of pitch canker—a disease which threatens thousands of acres of slash pine plantations and causes serious problems in slash and loblolly pine seed orchards.*
- *Control of brown-spot needle blight—the most important disease of longleaf pine. Research is centered on developing chemical and silvicultural controls and disease-resistant trees.*

Priorities for Continuing and New Research

- *Improve control techniques for cone and seed diseases in southern pine seed orchards.*
- *Determine influence of current and proposed forest management practices on disease incidence and resultant damage.*

- *Develop techniques to prevent, contain, or suppress fusiform rust outbreaks, including tree improvement.*
- *Evaluate and develop environmentally acceptable and specific chemicals for important forest disease pests.*

Prevention and Control of Forest and Range Fires

Current Program Emphasis

- *A multiple-index fire danger rating system.*
- *Use of prescribed fire to reduce wildfire occurrence and intensity.*
- *Properties of various forest fuels and their behavior during combustion.*
- *Application of sociological knowledge to problem of forest arson.*
- *Physics and chemistry of combustion.*

Priorities for Continuing and New Research

- *Find ways to predict blowup fire conditions.*
- *Perfect decision-making models for fire prevention and control.*
- *Assess damaging and beneficial effects of wildfire on forest resource values.*
- *Develop guidelines for reliable, local fire danger rating system.*

HARVESTING, PROCESSING, AND MARKETING OF WOOD PRODUCTS

Thirty years ago, forestry operations in the South from the stump to the actual sale of forest products differed little from the days of Jim Bowie, who operated a peckerwood mill in Louisiana. Since that time, the South has experienced a veritable industrial revolution, in the woods and mills, brought on by rising costs, increased demands for wood products, and scarcity of labor. This revolution must continue, for the lack of suitable processes, markets, and equipment may be a major limiting factor in the advancement of forest land management.

	Scientist Years		
	1975	1980	1985
Harvesting and Forest Engineering Systems	4	13	15
Properties, Processing, and Protection of Wood	52	59	63
Economics and Marketing of Wood Products	2	8	11
Total	58	80	89

Harvesting and Forest Engineering Systems

Current Program Emphasis

- *Harvesting systems and equipment to achieve maximum utiiization of each tree at minimum cost per unit volume. The recently developed tree puller can harvest and bunch pine up to 12 inches in diameter, with the central root mass intact, at a rate of 1.5 to 2 trees per minute. The machine is being evaluated on hardwoods up to 8 inches in diameter.*
- *Methods of harvesting forest residues for fiber and fuel. The mobile chipper, recently designed and being constructed, should harvest logging slash and residual standing trees and collect the chips for subsequent use.*
- *Special logging systems for adverse sites. For example: studies are investigating the economic feasibility of high-lead cable logging in steep terrain and wet sites, using small mobile-type systems.*
- *Machines and associated equipment best suited to supplying material to whole-tree chipping operations. More complete utilization has been brought closer to realization by the concept of whole-tree chipping.*
- *Productivity of conventional harvesting systems as related to specific equipment combinations, crew size, and site characteristics.*

Priorities for Continuing and New Research

- *Develop efficient, acceptable harvesting and regeneration systems for nonindustrial, private ownerships.*
- *Find new methods to conserve energy inputs into forest production.*
- *Perfect system of producing whole-tree chips on site for flaking or fiber processing, economically delivered to the mill.*
- *Develop equipment for harvesting total biomass with minimum soil impact.*
- *Compute detailed data on efficiency and costs of logging systems.*

Properties, Processing, and Protection of Wood

Current Program Emphasis

- *Structural flakeboards, medium-density fiberboards, composite-type panel material and composite lumber from pi and hardwood for exterior an interior use in building construction.*
- *New adhesive systems from nonpetrochemicals, such as ba extract, and improved adhesiv for southern pine plywood an reconstituted wood.*
- *Systems approach to coordinate the harvesting, breakdown, processing, and drying furniture parts from low-grade hardwoods.*
- *Better protective wood finishes to meet southern climate conditions. Several sta and copper-chromium finishes have been developed that provide attractive, and long-lastin finishes on southern pine in exterior exposure. A new woo preservative treatment has bee developed that reduces pollution, permits multi-treatments, and is cost effective.*

asic research on fundamental
perties of wood. This work
road in scope, ranging from
dies on anatomical and physi-
properties to the chemical
position of wood and bark
n both pines and hardwoods.

ligh-yield, nonpolluting
chanical pulping process for
thern pines.

lew methods for protecting
od in storage and use from
ects and decay.

ligh-temperature drying of
thern pine. A system has
n developed that is more
rgy efficient and faster than
viously used systems.

ystems to make wood
cessing industries energy self-
ficient. A new green-fuel
rner is being developed to
ect-fire dry kilns.

Priorities for Continuing and New Research

lake more efficient use of
-quality hardwoods.

icrease use of hardwoods
fiber, solid wood products,
l fuel.

- *Develop durable and economical construction systems that make efficient use of materials and have low energy requirements.*
- *Improve adhesives and processing systems for producing high-performance wood products.*
- *Reduce processing energy and increase yield in manufacture of wood products.*

Economics and Marketing of Wood Products

Current Program Emphasis

- *Weight scaling of logs for measuring products other than sawtimber and reflecting volumes of finished products.*
- *Simplification of forest product specifications.*
- *Role of retail building supply dealers and building contractors in marketing building materials.*
- *Methods for marketing wood residues.*

Priorities for Continuing and New Research

- *Evaluate economics of recovering logging residues, versus use of alternative fuels, for plant energy. Develop marketing programs for these residues.*
- *Investigate use of wood by-products for energy.*
- *Determine markets for small diameter timber where growth exceeds drain.*
- *Compare economics of in-woods sorting to merchandising at a mill yard.*
- *Identify merchantable harvesting limits as affected by fuel values.*

FOREST WATERSHEDS, SOILS, AND POLLUTION

Any use of forest lands has environmental impact—good and bad. As forest management intensifies in the South, protection and enhancement of site productivity and air and water quality become even more important considerations.

	Scientist Years		
	1975	1980	1985
Watershed Protection and Management	19	29	36
Soil, Plant, Water, and Nutrient Relationships	3	12	16
Alleviation of Soil, Water, and Air Pollution	10	23	35
Total	32	64	87

atershed Protection nd Management

Current Program Emphasis

- *Levels of sediment and trients in surface runoff and ound water that occur nat- ally on forested watersheds.*
- *Source of excessive sediment d stormflow in forested areas.*
- *Magnitude and duration of trient, water, and soil losses duced by intensive forest prac- es, including harvesting, road ilding, and site preparation.*
- *Forest practices guides that rmit forestry operations thout adverse impact on vironment.*

Priorities for Continuing and New Research

- *Develop forest management ternatives that minimize non- int source pollution and meet ality standards.*
- *Identify impact of intensive e preparation on quality and eld of water on different types watersheds.*
- *Develop guidelines to minimize soil erosion and sedimentation resulting from road building, harvesting, and site preparation.*
- *Evaluate impacts of vegetation control methods—chemical, mechanical and fire—on water quality and quantity.*
- *Collect data to develop criteria for stream side management.*

Soil, Plant, Water, and Nutrient Relationships

Current Program Emphasis

- *Nutrient cycling and physical and biological conditions within natural forest ecosystems. From these base data, changes caused by varying levels of forest management can be identified.*
- *Silvicultural practices that maintain and enhance forest soil productivity on a wide variety of sites.*

Priorities for Continuing and New Research

- *Quantify short- and long-term effects of intensive culture and complete-tree utilization on physical and chemical soil properties.*
- *Develop predictive models for site productivity based on soil-plant-water nutrient relationships.*
- *Identify types of nutrients depleted or lost from soil through intensive culture and complete tree utilization. Develop guidelines to replace nutrients lost.*
- *Identify relationship between prescribed burning, nitrogen loss, fertilization, costs, and environmental risks.*
- *Develop silvicultural treatments to alter nutrient cycling.*

Alleviation of Soil, Water, and Air Pollution

Current Program Emphasis

- *Methods of prescribed burning with minimal impact on air quality.*

- *Site treatments that minimize adverse effects of timber harvesting operations on the soil and water resource. Short-term effects of skid trails, landings, and temporary roads are included in these studies.*
- *Effects of land- and water-use practices on quality of water entering streams and reservoirs.*

Priorities for Continuing and New Research

- *Develop site preparation and harvesting methods to minimize soil disturbance and maintain soil quality.*
- *Find ways to reclaim abandoned strip mine areas.*
- *Identify impact of forestry on water, air, and soil as compared to baseline levels.*
- *Find environmentally acceptable techniques for use and disposal of various waste materials and their combinations.*
- *Analyze short- and long-term effects of pesticide application on soil, water, and air.*

FOREST RANGE, WILDLIFE, AND FISHERIES HABITAT DEVELOPMENT

Outputs from southern forests include far more than timber. At last count, more than 60 million acres of forest range were being grazed by livestock, either seasonally or yearlong. With proper management, both the total acreage grazed and the utilization of forage can be increased without harming wildlife habitat. Even under intensive forest management, southern pine forests provide relatively high yields of forage that can support a substantial cattle industry. The importance of southern forests to wildlife is readily recognized, with virtually every acre of forest land serving as habitat for one or more species of game or nongame birds and mammals. The job of research in this area is to develop ways to produce timber, forage, and a wide variety of wildlife and fishery habitats through integrated management practices.

	Scientist Years		
	1975	1980	1985
Management of Range Resources	3	6	13
Wildlife and Fish Habitat	17	35	49
Total	20	41	62

Management of Range Resources

Current Program Emphasis

- *Responses of vegetation and livestock to timber management measures.*
- *Grazing systems and herd management practices that improve quality of range livestock and the amount and nutrition of forage.*
- *Range and livestock management programs that permit concurrent and harmonious production of timber and forage resources.*
- *Range characteristics including the identity, physiological requirements, and nutritive value of forage plants for a wide variety of forest types.*
- *Methods for controlling undesirable range plants through fire, chemical, mechanical, and biological measures.*

Priorities for Continuing and New Research

- *Identify the impact of grazing on each of the other multiple-use objectives for forest land. Identify those grazing systems offering the best management alternative for multiple use.*
- *Examine economics and impacts of livestock grazing programs on wildlife for the southern National Forests.*
- *Provide range management cost/benefit analyses for major forest types.*
- *Identify responses of forest vegetation to grazing.*
- *Develop habitat management strategies for unique and endangered and threatened plant communities.*

Wildlife and Fish Habitat

Current Program Emphasis

- *Habitat-management guidelines that permit production of both timber and game species, notably white-tailed deer, bobwhite quail, turkey, and squirrels.*
- *Habitat requirements for nongame birds and mammals and for endangered wildlife.*
- *Methods for improving fore wildlife habitat through such measures as seeding, planting, prescribed burning, spraying, and fertilizing.*
- *Predictive models for estimating wildlife carrying capacity for various forest sit under varying conditions of timber management.*
- *Guides for managing green-tree reservoirs as waterfowl habitat and for high-quality timber production.*

Priorities for Continuing an New Research

- *Evaluate effects of intensive forest management practices wildlife habitat and species diversity.*
- *Determine impacts of clear-cutting creek-bottom hardwo on fisheries, wildlife, and wildlfe habitat.*
- *Develop optimum strategie for protecting and managing riparian lands for waterfowl and forest wildlife.*
- *Identify impacts on wildlife of pine monoculture as oppos to mixed stands.*
- *Determine effects of intensi game and timber managemen on the rest of the forest community.*

FOREST RECREATION AND ENVIRONMENTAL VALUES

Trees and forests provide a wide variety of amenity or nonconsumptive values that are steadily assuming greater significance to the American public. This is particularly true in the South, where use of forest lands for recration has increased almost 40 percent since 1970. The goal of research in forest recreation and environmental values is to identify these values and increase their availability to all user groups.

	Scientist Years		
	1975	1980	1985
Outdoor Recreation	15	9	20
Rural and Urban Environmental Enhancement	0	6	15
Total	15	15	35

Outdoor Recreation

Current Program Emphasis

- *Impact of large numbers of people on forest ecosystems.*
- *Guides for recreation site selection, design, and management techniques to accommodate crowds.*
- *Psychological needs of people for recreation and their preferences.*
- *Benefit/cost analyses of forest recreation alternatives.*

Priorities for Continuing and New Research

- *Investigate new incentives to encourage recreational development in the private sector for public use.*
- *Identify social loading capabilities, by recreational activity, for planning user density. Develop methods for determining use loading and design capacities of outdoor recreation facilities.*
- *Develop effective approaches to interpret forest management practices to forest visitors.*
- *Identify consequences of closure of private land to increasing recreation demand.*
- *Develop benefit/cost ratios for outdoor recreation facilities and activities.*
- *Determine the demand for the various types of recreation during the next 20 years.*

Rural and Urban Environmental Enhancement

Current Program Emphasis

- *Selection of tree species and strains best adapted for urban areas and for special purposes.*
- *Culture and improvement of greenbelts around urban areas.*
- *Stress factors affecting tree growth in urban areas.*

Priorities fo Continuing New Resear

- *Predict effects of urbaniz on forest lands for the next 20 years.*
- *Determine psychological benefits of urban greenbelt and metropolitan forests.*
- *Develop techniques for i tensive culture and manag of tree species for urban us*
- *Identify impacts of feder indecision on investment i conservation programs by private landowners.*
- *Determine effects of the conversion of forest land t other uses on ecological ba*

IMPLEMENTATION OF THE PLAN

Full implementation of the plan is contingent on funding, research staffing, facilities, and current research program commitments. Research planning information is used in the budget building process. Legislators at the local and national levels will be provided with these planning documents in support of budgetary requests. Shifts in emphasis are possible, however, with current resources through reprogramming. Also, new programs can be initiated as current studies are completed, such as the recent program efforts being developed in the key problem areas of nonpoint source pollution, maintenance of site productivity, and energy conservation. Scientists and research administrators will use the plan as a guide, both in developing new program initiatives and redirecting existing efforts.

Research planning is a continuous process. Scientists in the 1974 Southern Task Forces identified and evaluated research needs in six Task Force reports. The 1977 regional conference brought together research users who identified and rated current research needs, issues,, and concerns in the South. Finally, in 1978, task forces composed once again of scientists evaluated the problems identified in the 1977 conference. Continuation of the joint, long-range planning process will be necessary to meet future needs and changing priorities.

The National Program will reflect both regional and national issues and priorities of forestry research conduct and content. It will strengthen the research contribution to the 1980 recommended Resources Planning Act program, enhance Federal/State research planning cooperation, and insure the involvement of consumer and user groups in research planning. This regional plan, together with the National Program, will enhance coordination among research organizations in the South, and will provide documentation for identifying specific thrusts that are needed in the southern region. Ultimately the Forest Service and State Agricultural Experiment Stations and Forestry Schools in the South hope such highlighting of forest resources research will result in a greater awareness of these resources and more effective research directed toward their wise use and conservation.

APPENDIX

SOUTHERN REGION

Scientist Years (SY's) for Forestry and Associated Rangelands Research for the State Agricultural Experiment Stations and Forestry Schools (SAES + F. Sch.), and U.S. Forest Service (US-F. Serv.) for 1975, 1980, and 1985.

	1975			1980			1985	
Research Program and Research Problem Area	SAES + F. Sch.	US-F. Serv.	Total	SAES + F. Sch.	US-F. Serv.	Total	SAES + F. Sch.	US-F. Serv.
	-----Scientist Years-----							
Multi-resource Inventory								
Appraisal	7	15	22	12	33	45	12	33
Alternative Uses	1	0	1	2	1	3	2	1
Evaluation	6	0	6	8	2	10	9	2
Subtotal	**14**	**15**	**29**	**22**	**36**	**58**	**23**	**36**
Timber Management								
Biology	37	58	95	44	76	120	49	81
Genetics	17	16	33	16	16	32	17	17
Economics	11	6	17	17	10	27	18	13
Subtotal	**65**	**80**	**145**	**77**	**102**	**179**	**84**	**111**
Forest Protection								
Insects	14	27	41	19	26	45	20	25
Diseases	14	19	33	15	20	35	16	19
Fire	1	17	18	3	11	14	4	11
Subtotal	**29**	**63**	**92**	**37**	**57**	**94**	**40**	**55**
Wood Products								
Harvesting	1	3	4	5	8	13	6	9
Processing	22	30	52	38	21	59	39	24
Marketing	2	0	2	7	1	8	10	1
Subtotal	**25**	**33**	**58**	**50**	**30**	**80**	**55**	**34**
Watersheds, Soils, and Pollution								
Watersheds	4	15	19	13	16	29	19	17
Soils	3	0	3	5	7	12	6	10
Pollution	2	8	10	6	17	23	8	27
Subtotal	**9**	**23**	**32**	**24**	**40**	**64**	**33**	**54**
Forest Range and Wildlife								
Range	1	2	3	1	5	6	3	10
Wildlife	9	8	17	19	16	35	24	25
Subtotal	**10**	**10**	**20**	**20**	**21**	**41**	**27**	**35**
Recreation and Environmental Values								
Recreation	14	1	15	5	4	9	11	9
Environment	0	0	0	4	2	6	9	6
Subtotal	**14**	**1**	**15**	**9**	**6**	**15**	**20**	**15**
TOTAL	166	225	391	239	292	531	282	340

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for the

National Program of Research for Forests and Associated Rangelands

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S. Department of Agriculture, Forest Service, General Technical Report SO-20

Root Parasites of Southern Forests

LYTTON J. MUSSELMAN
and WILLIAM F. MANN, JR.

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Summary

The five families of root parasites of the South are discussed relative to selection of hosts, ecology, and potential for damage to commercial species. An identification key to all genera of root parasites is included. Plants and flowers of 29 species are illustrated and their distribution in the South mapped.

Acknowledgments

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Disclaimer

If herbicides are handled, applied, or disposed of improperly, they may be injurious to humans, domestic animals, desirable plants, and pollinating insects, fish, or other wildlife, and may contaminate water supplies. Use herbicides only when needed and handle them with care. Follow the directions and heed all precautions on the container label.

Root Parasites of Southern Forests

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Foreword

Root parasitic plants were virtually unknown to southern foresters until 1969 when it was reported that senna seymeria *(Seymeria cassioides)* was killing 3- and 4-year old slash pines *(Pinus elliottii)* in a large plantation in northwest Florida (Mann and others (1969). Since then several publications have appeared on senna seymeria, but other root parasites that occur widely in the South have been ignored.

Perhaps the most familiar parasitic plants are the mistletoes that penetrate stems and branches of trees and shrubs. Root parasites act similarly below ground, forming specialized knob-like organs termed haustoria that attach to and penetrate the roots of neighboring plants to provide a pathway for the transfer of water and food from the host to the parasite. These parasites, part of a heterogenous group of flowering plants, depend on host plants for their subsistence in varying degrees. Several species, in fact, are capable of maturing and producing seed without attachment to a host. Some parasites attach to a wide variety of hosts, while others are much more specific.

Root parasites can be divided into two categories based on the presence or absence of chlorophyll. Holoparasites lack chlorophyll, cannot produce their own food, and are entirely dependent on host plants for food and water. Semiparasites (sometimes referred to as hemiparasites) contain chlorophyll and are able to produce all or part of their own food. The green appearance of these plants belies their parasitic nature, so they can easily be overlooked as pathogens of other plants. Root parasites are diverse in growth form and habitat and may be annuals, biennials, perennials, shrubs, vines, or trees. A list of all native root parasites of the South is given in Appendix I. An excellent volume by Kuijt (1969) deals with all parasitic angiosperms.

The efforts that led to this paper were begun because experience with senna seymeria indicated that intensive site preparation practices can lead to damage to commercial tree species by root parasites. The research, a cooperative effort of the U.S. Forest Service's Southern Forest Experiment Station and Old Dominion

University, was initiated to determine if southern root parasites are pathogens of commercial forest species. Research has consisted of surveys and of field and greenhouse studies. This booklet, based largely on the investigations, gives geographic range, host selection, habitats, and keys for identification of the most prevalent southern root parasites. We believe it will be a valuable tool for botanists and practicing foresters.

One of the objectives of the 2-year cooperative agreement was to determine if native root parasites would attach to trees of commercial importance in greenhouse cultures. Susceptible hosts could thereby be identified and necessary precautions taken in planting and maintaining the hosts in areas where the parasite was known to occur. Such studies are only indicative of the potential for a species to be a suitable host, and many other field conditions, such as the influence of microorganisms and exudates from non-host species, may influence these phenomena. We tried to collect seeds of every native parasite in the southern states. This proved difficult because of low or sporadic fruit set in some *(Pyrularia, Schoepfia)* and the difficulty of locating fertile plants of others (for example, *Nestronia* and *Agalinis heterophylla)*. We were unable to grow some parasites because they have germination requirements we do not understand *(Conopholis* and *Epifagus)*.

For pot studies, seeds were collected from various sites throughout the South. Where possible, more than one seed source per species was used to record any variation in vigor among populations of the same parasite. Immediately after collection, seeds were mailed to the Alexandria Forestry Center where they were stored in airtight jars at 3°C until used. They were then sown in pots with a mixture of peat moss and vermiculite containing a 1-year-old host plant. Species chosen for hosts (listed in Appendix II) are the most important species in the South for timber and fiber production.

Most seeds germinated readily, and within 6 months many plants had begun to flower or initiate flowering. Pots were broken down at this time or when the parasites bolted (initiated height growth). When the plants were ready for examination, soil was gently washed from the roots of host and parasite, which were then carefully examined for haustoria. All haustoria, regardless of size, were counted. Each haustorium represents an invasion of the vascular tissue of the host and thus the number of haustoria was considered an indication of parasite vigor and host damage. Numerous self-haustoria were produced in some parasites *(Aureolaria grandiflora, A. virginica, A. laevigata, A. flava, Macranthera flammea, Dasistoma macrophylla, Agalinis purpurea,* and *Ximenia americana)*. These are haustoria that attach to the roots of the parasite itself. Self-haustoria are included in the totals, but we estimate that they amounted to less than 1 percent of the total number of haustoria.

We found little basis for assuming any sort of host specificity in most native parasites (Appendix III). In other words, most native root parasites, given the opportunity, attack almost any species of woody plant. This is particularly significant in light of the widespread distribution of many parasites. While it remains to be seen if infestations of these plants in commercial stands will cause damage of the magnitude of that caused by senna seymeria (Mann and others 1969), foresters should be aware of the pathogenic potential of these plants and which hosts they will attack.

Little is known about the control of southern root parasites. Succulent annuals and perennials can undoubtedly be controlled with 0.5 lb. ai of 2,4,5-T per acre in a water carrier and applied in a total volume of 5 pounds per acre. Woody species like *Ximenia* will probably require 2 pounds ai of 2,4,5-T per acre, also applied in 5 gallons of water. However, their resistance to the various herbicides has not been determined, so some small-scale trials would be needed to guide operational programs.

Fire does not seem like a good alternative for control, even in pine plantations, because work should be started before the pines are fire hardy. Then, too, annual species are often dead before weather is suitable for prescribed burning, and the seeds for a new crop have already been shed.

In the past 10 years several compounds that stimulate germination in the root parasites *Striga* and *Orobanche* have been discovered and synthesized. One of these is strigol, isolated from the roots of corn and other plants. Strigol has been found to be a potent germination stimulant for witchweed (Cook and others 1972). Recently Johnson and others (1976) described synthetic germination stimulants which caused a high rate of germination in both *Striga* and *Orobanche* even at very low concentrations. We ran some preliminary tests using both compounds on seeds of most species of root parasites in the South. Most seeds of these species do not respond to these stimulants; therefore control of native root parasites with these compounds does not seem feasible. We did not, however, test the effect of ethylene (a germination stimulant used widely to control witchweed) on parasites discussed in this paper.

Identification Key to Root Parasites of the Southern United States

The purpose of this key is to provide a simple means of identifying ny root parasite growing in the South. Technical terms have been kept o a minimum to allow anyone without botanical training to use the key, ut a short glossary is provided. Most genera included in the key are lustrated. While every effort has been made to provide for the identifi-ation of plants in vegetative condition, to determine many species ccurately, flowers are needed.

The key employs dichotomies or branches to lead to the correct lentification of a plant. Of two choices in each couplet, only one will pply to the plant being identified. For example, if the plant contains hlorophyll, the second line of couplet 1 is true. The user is then directed o couplet 6. If the plant is woody, the first line of couplet 6 will then ead to couplet 7 and so on until the plant is identified. If identification roves exceptionally difficult or if determination is needed immediately ut all parts of the parasite are not yet developed, it may be possible o get assistance by contacting the curator of the herbarium at a ate university.

1. Plants without chlorophyll; brown or yellow; leaves reduced to scales . . . .

1. Plants with chlorophyll; leaves normal . . . .

---

2. Main stem uniformly thick; fruit fleshy; seeds very hard, shiny; plant perennial . . . . *Conopholis americana* (p. 61

2. Main stem thickest at base, tapering to top; fruit dry; seeds dust-like, dull; plants annual . . . .

---

3. Flowers in late fall; found only with beech; underground portion of plants swollen, with hook-like outgrowths . . . . *Epifagus virginiana* (p. 60

3. Flowers in spring; found with various hosts; lacks hook-like outgrowths on underground portions . . . . 4, *Orobanche* sp

---

4. Stem whitish; flowers solitary on long stalk . . *Orobanche uniflor*

4. Stem yellow-brown; flowers numerous, crowded on main stem . . . .

---

5. Calyx with five distinct lobes; mainly western . . . . *Orobanche ludovician*

5. Calyx with four lobes; rare species of east coast . . . . *Orobanche minor* (p. 63

---

6. Trees or shrubs . . . .

6. Herbs, not woody (except at base) 11

---

7. Thorns present (widespread shrub of Florida) . . . . *Ximenia americana* (p. 16

7. Thorns absent . . . .

---

8. Leaves alternate . . . .

8. Leaves opposite 1

9. Leaves shiny on upper surface; evergreen, small tree of southern Florida; flowers small, red . . . . . . *Schoepfia schreberi* (p. 15).

9. Leaves dull on upper surface, deciduous shrub of the Appalachians; flowers small, greenish, inconspicuous . . . . *Pyrularia pubera* (p. 21).

10. Bark of young twigs green; rare shrub of the southern Appalachians . . . . *Buckleya distichophylla* (p. 19).

10. Bark of young twigs reddish brown; uncommon shrub of the Piedmont . . . . *Nestronia umbellula.*

11. Leaves alternate . . . . 12.

11. Leaves opposite (though upper leaves associated with flowers may be alternate) . . . . 16.

12. Leaves lobed . . . . 15.

12. Leaves not lobed . . . . 13.

13. Broadest leaves less than 2 cm wide . . . . 14.

13. Broadest (basal) leaves more than 2 cm wide . . . . *Schwalbea americana* (p. 53).

14. Leaves hairy; main stems prostrate on ground; fruit spiny . . . . *Krameria lanceolata* (p. 67).

14. Leaves not hairy; main stems erect; fruit not spiny . . . . *Comandra umbellata* (p. 20).

15. Stem leaves with 5 or more lobes; corolla yellow to purplish; seeds egg-shaped; widespread but most common in mountains . . . . *Pedicularis canadensis* (p. 52).

15. Stem leaves with 5 lobes or less; bracts scarlet (rarely yellow); corolla yellow; seeds angular; northern . . . . . . *Castilleja coccinea.*

16. Some leaves (at least the lowermost) lobed or dissected 20

16. Leaves not lobed (a few teeth may be present) 17

---

17. Broadest (basal) leaves scale-like, absent, or never wider than 2 cm 19

17. Broadest (basal) leaves always wider than 2 cm 18

---

18. Leaves and stem hairy, rough to the touch; flowers blue to red-purple; seeds numerous, shiny, black . . . . *Buchnera americana* (p. 48)

18. Leaves and stem not hairy, smooth to the touch; flowers bright yellow; seeds numerous, dull, brown . . . . *Aureolaria laevigata* (p. 42)

---

19. Flowers white with a spot of yellow on the upper lip; fruit with one to four smooth seeds; plants 0.5 m tall or less . . . . *Melampyrum lineare*

19. Flowers pink or purple (one or two plants in a large population may have white flowers), fruit with numerous honeycombed seeds; plants 0.5 m tall or more . . . *Agalinis* spp. (p. 26

---

20. Plants perennial (buds present on rootstock, last season's fruiting stalks attached to living roots) 21

20. Plants annual or biennial (although often very large) 23

---

21. Plants with dense short, soft hairs . . . *Aureolaria virginica* (p. 46)

21. Plants without dense hairs 22

---

22. Plants to 2.0 m tall, sparsely branched, upper leaves not lobed; widespread . . . . *Aureolaria flava* (p. 38)

22. Plants to 1.5 m tall, much branched; upper leaves lobed; common in Ozarks . . . . *Aureolaria grandiflora* (p. 40)

23. Flowers pink; upper stem leaves with two prominent lobes at base (very rare plant in the South) . . . . *Tomanthera auriculata.*

23. Flowers not pink; upper stem leaves usually lacking two prominent lobes at base . . . . 24.

24. Plants densely covered with sticky hairs . . . . 25.

24. Plants without sticky hairs . . . . 26.

25. Ultimate sections of leaves thread-like, less than 1 mm wide; flowers less than 2 cm long . . . . *Seymeria cassioides* (p. 54).

25. Ultimate sections of leaves not thread-like, more than 1 mm wide; flowers more than 2 cm long . . . . *Aureolaria pedicularia* (p. 43).

6. Basal leaves with more than 8 main lobes (rare) . . . . *Pedicularis lanceolata.*

6. Basal leaves with less than 8 main lobes . . . . 27.

7. Basal leaves 10 cm wide or more . . . . *Dasistoma macrophylla* (p. 49).

7. Basal leaves 5 cm wide or less . . . . 28.

8. Plants more than 1.5 m tall; basal stem leaves more than 6.0 cm long; flowers orange; Gulf Coastal Plain . . . . *Macranthera flammea* (p. 50).

8. Plants less than 1.5 m tall; stem leaves less than 4.0 cm long; flowers yellow; more widespread . . . . *Seymeria pectinata* (p. 56).

Parasite Descriptions

An attempt was made to photograph each species in its natural habitat, but in some cases we had to use plants from our pot studies to obtain an adequate picture of a typical parasite. Descriptions of plants are based almost entirely on our field observations. Where it was not possible to examine a plant for a particular feature such as a flower or fruit, we have based descriptions on herbarium material and botany manuals. The descriptions are purposely brief. Characters distinctive for that species are emphasized. Short discussions of families and larger genera are also provided.

Range Maps

Maps included indicate the approximate range of the parasites; that is, a broad area in which the plant may or may not be found. In some cases such as *Buckleya distichophylla* and *Orobanche minor*, where species are extremely rare or local, the counties have been indicated by dots.

These ranges have been taken from literature (Radford and others 1968, Pennell 1935, DeFillips 1968), herbarium data and field work conducted over the past 10 years.

Olacaceae
(Olax Family)

Olacaceae (Olax family)

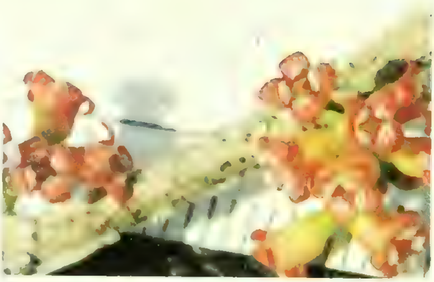
This family of woody plants is mostly tropical and is represented in North America by two species which occur only in Florida. Both have simple alternate leaves and may flower at any time of the year.

Schoepfia schreberi/Whitewood

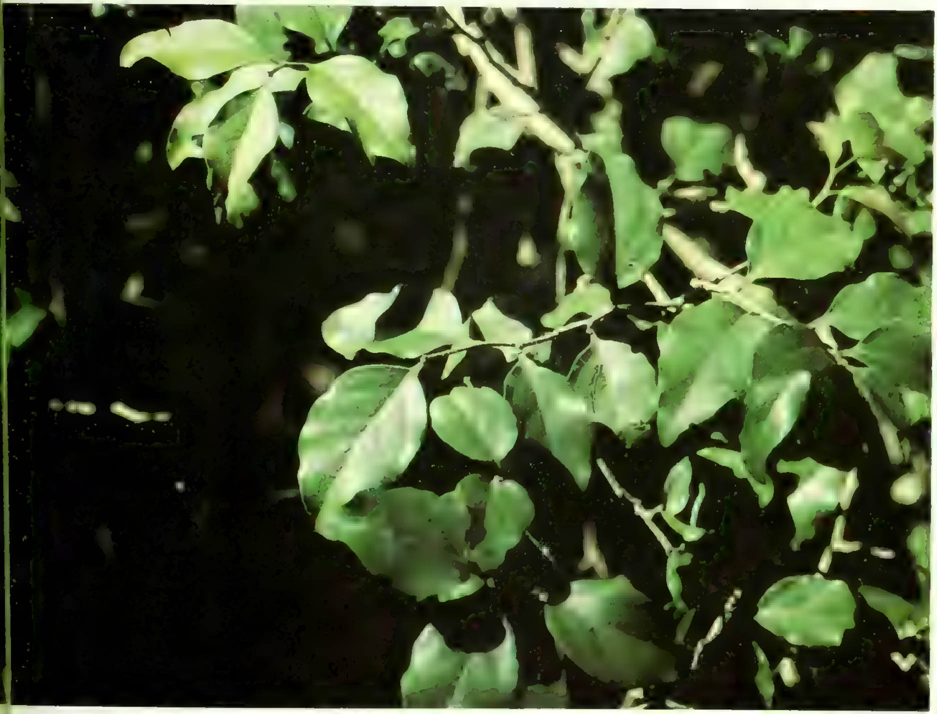
Whitewood is a small tree that occurs in hardwood hammocks in southern Florida and in the West Indies. Older portions of the trunk may be white, hence the common name.

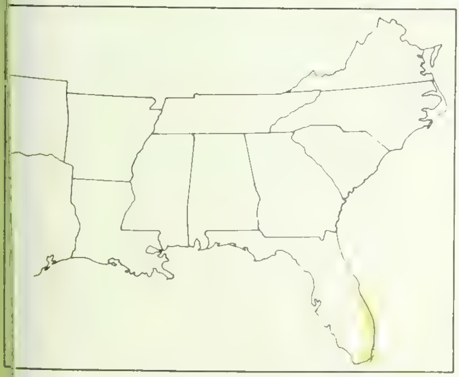
The host selection of whitewood is poorly known but appears to be broad including poison ivy, live oak, and Virginia creeper.

Flowers



Schoepfia schreberi





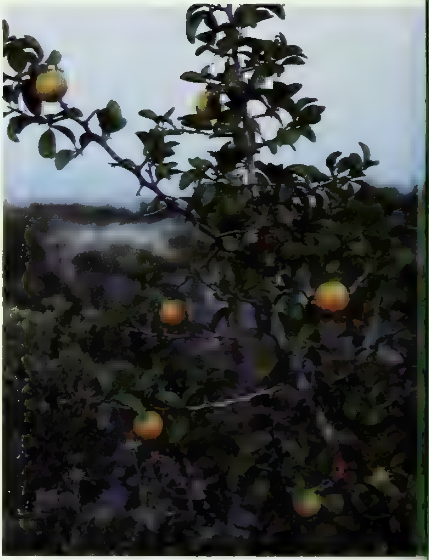
TREE: up to 4 m tall. STEMS: older portions often whitish. LEAVES: alternate, 5.5 cm long, 2.7 cm wide, tapering to tip. FLOWERS: very small, 2 mm wide, bright red, borne in small clusters near the tips of younger branches. FRUIT: about the size of a small olive with one seed.

Ximenia americana/Hog plum, Tallowwood

Unlike *Schoepfia*, *Ximenia* is a shrub and is widespread throughout central and southern Florida. It is particularly abundant in the sand pine scrub area, where it forms a conspicuous part of the vegetation.

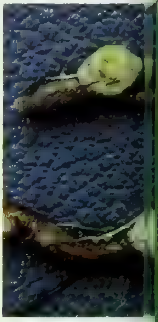
Ximenia is seldom over 3 m tall. The entire plant is covered with short, sharp thorns. The leaves have a definite yellowish cast, are somewhat succulent and rather brittle. The small white flowers have a pleasant fragrance and the fruit, about the size of a small plum, has a sweet, juicy pulp.

The haustoria of *Ximenia*, often more than 3 cm wide, are the largest of any root parasite in North America. They apparently live for many seasons, which accounts for their size. Large slit-like openings, which are scars caused by *Ximenia* haustoria, are frequently found on the roots of neighboring plants. A single parasite may inflict serious damage by forming hundreds of haustoria on host roots in a single season.

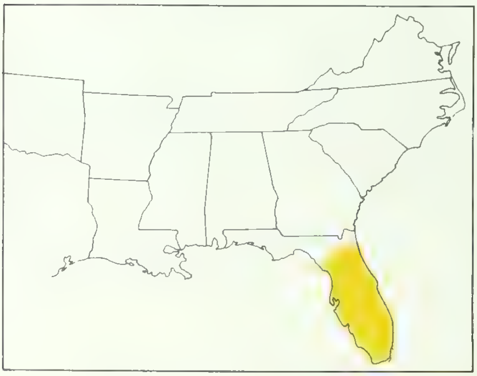


Ximenia americana with fruit

Flowers



Haustoria



SHRUB: many branches. **STEMS:** up t
3 m; armed with short, sharp thorns.
LEAVES: up to 4 cm long, 2.2 cm wide
broadest at the middle. **FLOWER:** sma
4 mm wide; petals white, hairy; fragran
FRUIT: 4 cm long, 2 cm wide, one seed

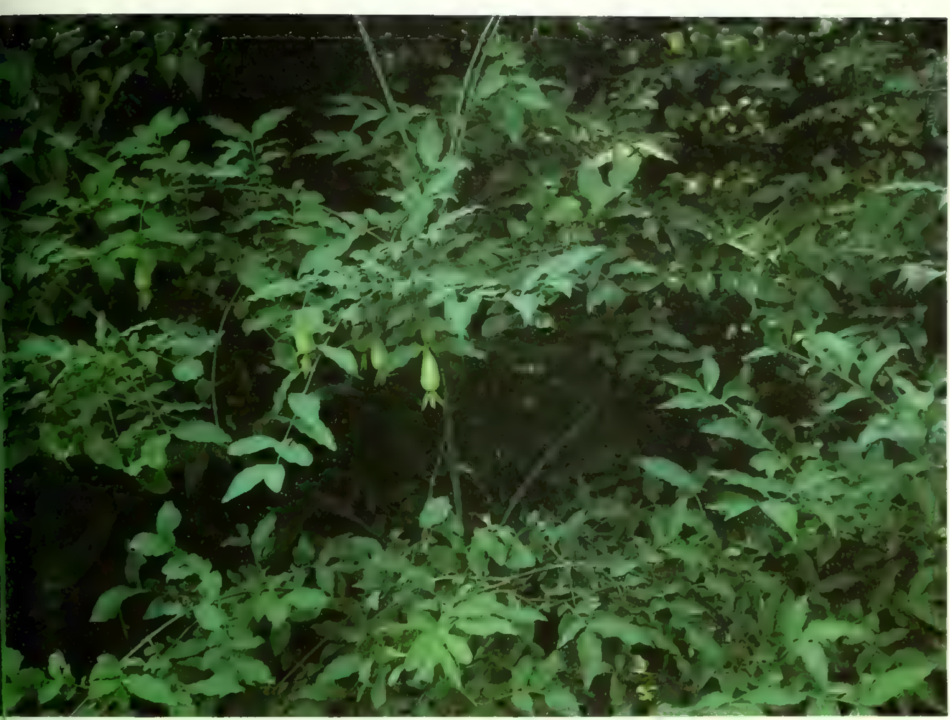
Santalaceae
(Sandalwood Family)

Santalaceae (Sandalwood family)

This is a large tropical family which includes the sandalwood tree *(Santalum)* of commerce. In North America it is represented by four genera: *Buckleya, Nestronia, Pyrularia,* and *Comandra. Comandra* is a perennial rhizomatous herb. The other genera are shrubs or small trees. Each genus has only one species.

The habitats of the three woody species are somewhat different. *Nestronia* grows in dry pine woods in the Piedmont where we have seen it form abundant, large haustoria on shortleaf and loblolly pine. *Buckleya* is known from only eight locations in the southern Appalachians. Both *Buckleya* and *Nestronia* have small, opposite leaves. *Pyrularia,* also found in the southern Appalachians, is common and often abundant. It has alternate leaves. *Comandra* also has alternate leaves and is one of the more widely distributed vascular plants in North America.

The flowers of the three shrubs are small, greenish, and inconspicuous. *Buckleya, Nestronia,* and *Pyrularia* are dioecious. *Comandra,* on the other hand, has attractive, small, perfect, white flowers. The fruits of all species are fleshy and contain a single seed. Haustoria in this family resemble those of *Ximenia.*

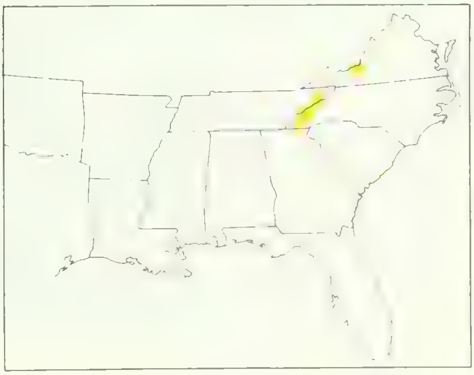


Buckleya distichophylla/ Buckleya, piratebush

Buckleya distichophylla with fruit

Buckleya is familiar to most botanists. Despite its well documented rarity, there is no published nformation on the culture of this shrub. It has been prepared for he threatened species list.

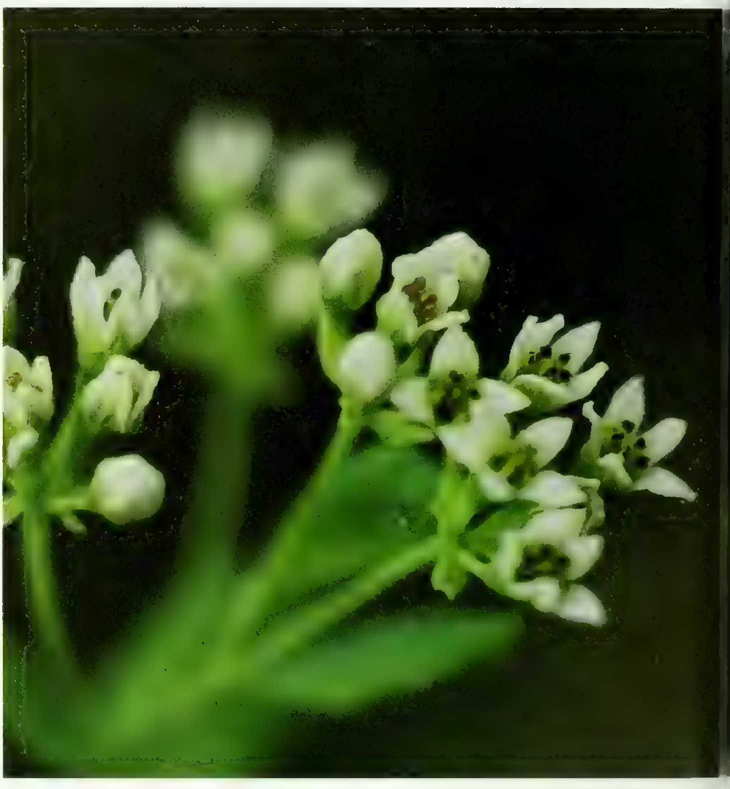
Buckleya grows on steep rocky lopes always in association with hemlock *(Tsuga)*. This has led to peculation that it is restricted in its host preference to this genus of ymnosperms. However, *Buckleya* will form haustoria on a variety of osts both in nature and culture. At the University Botanic Garden in Copenhagen, it thrives on the roots f a yew *(Taxus)*. In our studies, parasitized the roots of pines, ypress, and several hardwoods. We were able to achieve about 60 ercent germination of the seeds fter cold treatment.



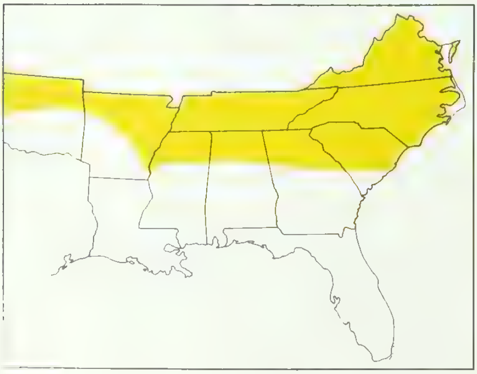
SHRUB: many stems arising from large white rhizomes. STEMS: up to 3.5 m tall, lower portions of stem white. LEAVES: up to 6 cm long, 1.5 cm wide, tapering to a narrow point. The leaves are so arranged as to give the impression that the plant has large, compound leaves. FLOWERS: unisexual, green, inconspicuous, borne at the tips of lateral twigs in early spring. The female flowers have prominent bracts which persist on the fruit. FRUIT: up to 4 cm long, 1.5 cm wide, greenish yellow with white protuberances.

Comandra umbellata/Comandra, bastard toadflax

Although this is the only herbaceous member of this family in North America, it has a wide distribution. It prefers open, sunny, often dry areas such as prairies, roadsides, and openings in dry woods. *Comandra* has a remarkably broad host range of over 200 species, including ferns, gymnosperms, and flowering plants. The host range and life history are discussed by Piehl (1965). The colorful common name, bastard toadflax, comes from the resemblance of this species to the toadflax *(Linaria)*. The considerable variation among plants withi the species has led some botanists to recognize several species.

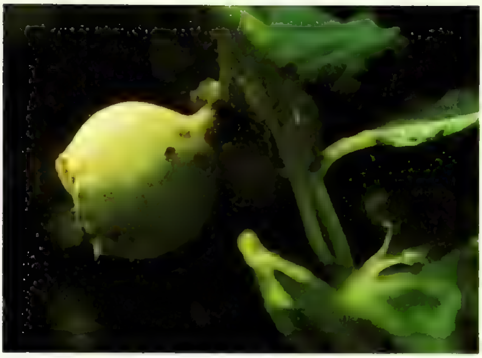


Comandra umbellata



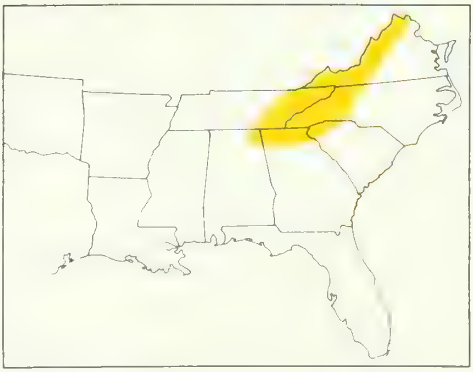
PERENNIAL: from deep rhizomes. STEMS: up to 0.5 m tall, sparsely branched. LEAVES: up to 4.5 cm long, 1 cm wide, alternate, often densely crowde on the stems. FLOWERS: with five whit sepals, borne in spring, 1 cm across. FRUIT: somewhat fleshy, one seed.

Pyrularia pubera/Buffalo nut, oilnut



Pyrularia is a very common shrub that may be found in almost any drier site in the southern Appalachians. It is often vigorous in forests disturbed by logging, fire, or wind and ice damage. The fruits are not usually abundant and are reported to be very poisonous.

SHRUB: from thick rhizomes. STEMS: up to 2 m tall, sparsely branched with gray-brown bark. LEAVES: clustered on short shoots, up to 10 cm long, 3.5 cm wide, margins entire to wavy, somewhat fleshy and easily broken when fresh. FLOWERS: small, unisexual, green, borne in drooping clusters. FRUITS: 1.5 cm in diameter, round, with a crown-like ridge on the bottom, one seed.



Scrophulariaceae

(Figwort Family)

Scrophulariaceae (Figwort family)

This is the largest and most widespread family of root parasites in the southeastern United States, with 11 genera and about 30 species. More than half of these species are in the genus *Agalinis*, a group that is taxonomically difficult. Some parasites such as *Agalinis purpurea* and *Aureolaria pedicularia* are found throughout the South and often in very large populations. Other species such as *Macranthera flammea* and *Agalinis divaricata* are restricted in their range but often numerous where found. Still others are rare, as is *Schwalbea americana*, which is known from only three small populations.

The Scrophulariaceae is a natural group. It is easy to distinguish plants of this family. All southern species are herbaceous. The leaves are always simple (although often dissected) and opposite, except in *Pedicularis canadensis*, *Castilleja coccinea*, and *Schwalbea americana*. The flowers have five petals, five sepals, four stamens, and one ovary. For convenience, two parts of the corolla may be distinguished, the corolla tube, and the corolla lobes. The shap and size of the tube and the relative sizes of the lobes are useful in distinguishing species. Two general types of flowers are present in parasitic figworts. The first is found in *Aureolaria* wher the corolla lobes are at right angles to the tube and the mouth of the tube is open, like a trumpet. In the second corolla type, the five lobes are not spreading and the tube does no appear open. Such corollas are found in *Schwalbea, Pedicularis* *Melampyrum, Castilleja,* and *Macranthera.*

The fruit of all of the parasitic figworts is a capsule. Capsule structure is similar throughout the group.

Pedicularis, Melampyrum, Castilleja, Dasistoma, and *Schwalbea* all flower in the spring or early summer. All othe species flower in the summer or fall. The seeds of all species are small but there is considerable variation in seed size among the various genera. *Melampyrum* and *Pedicularis* have few seeds (10 or less) per capsule, while other genera have hundreds. Larger seeds are apparently distributed by ants, smaller seeds by wind or water.

Our tests have shown that most species lack specialized germination requirements. As expected, species of more northerly distribution or that grow at higher elevations in the mountains require a period of cold treatment to break dormancy.

The root systems of these plants are fibrous and often wiry. Roots are usually white or yellow and shallow in the soil. Haustoria may be borne at any point on the root system. Size of haustoria varies greatly between genera but tends to be uniform among species in the same genus. Largest haustoria, which may be as much as 10 mm in diameter, are those of *Aureolaria, Seymeria, Dasistoma,* and *Macranthera.* Haustoria of the remaining genera tend to be no larger than 1 mm. All haustoria have a yellowish substance at the host-parasite interface.

For many years, it was thought that certain genera were restricted to specific hosts. It has often been recorded that *Aureolaria pedicularia* restricted its host preference to members of the black oak group. Our tests over a 2-year period show clearly that this parasite will attach to almost any host. For example, *Aureolaria pedicularia* grew vigorously when parasitizing the roots of water tupelo. Other species will also grow on a variety of hosts. Thus, most of these plants can be considered to be potential parasites of commercial species.

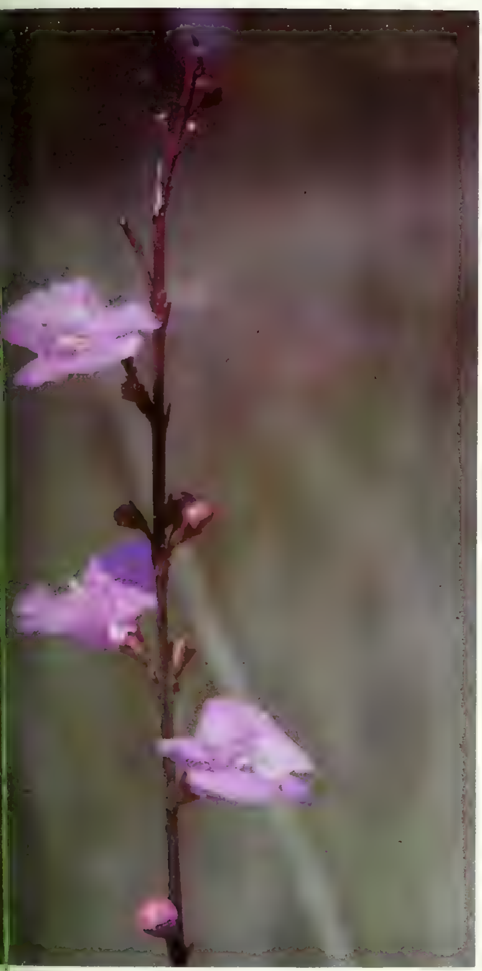
Agalinis/Gerardia

This is the largest group of root parasites in the South. As many as 30 species are recognized by some authors (Pennell 1935). The taxonomy of the group is confused and needs much work. Likewise, the nomenclature of the genus is tangled and has a complex history. The name *Gerardia* was formerly used not only for the plants now included in *Agalinis*, but also those now included in the genera *Aureolaria* and *Tomanthera*. *Gerardia* has been rejected under the rules of botanical nomenclature and should not be used at all. However, many manuals and keys still use it. Unfortunately, most species do not have widely accepted common names, even though Gerardia is often used as a common name for the genus as a whole.

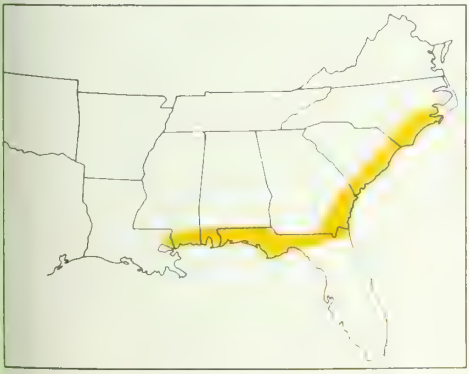
The genus is characterized by showy, often large, pink to purple (rarely white) flowers that appear in fall and persist for only one day. Flowers open two at a time per flowering branch and are usually necessary for critical identification of species. For example, the throat (interior of the tube) of the flower may have two yellow lines that guide insects to the pollen-bearing stamens (commonly called guidelines), the presence or absence of which distinguishes species. The size and shape of the sepals on the capsules may also be of taxonomic value. *Agalinis* seeds are brown to black and somewhat wedge-shaped, with a honeycombed surface. Vegetatively, species of *Agalinis* vary in overall size and in leaf structure. Leaves are generally opposite and always linear in shape. In *A. filicaulis* the leaves are reduced to very sm structures, and in *A. aphylla* leave are entirely lacking. Haustorial str ture is fairly uniform throughout the genus. *Agalinis linifolia* is the only perennial; all other species are annuals.

All gerardias typically grow in ope sunny areas in a variety of habitat For example, *A. aphylla* is almost entirely restricted to pine savanna *Agalinis purpurea* could be considered weedy, because it often grows along roads and on other disturbed sites. The genus reache its greatest diversity on the Atlanti and Gulf Coastal Plains, although three species, *A. fasciculata, A. purpurea,* and *A. tenuifolia,* are found throughout the South.

The parasitic behavior of these plants has been known for a long time. Our pot culture work indicat that *Agalinis* has the broadest hos range of any root parasite in the South. All species that we investigated attached to a variety of pine and hardwoods. All host species were parasitized by at least one of the eight species of *Agalinis*. At present it appears that there is no definite host preference by any species. In some cases over 2,000 haustoria were formed in 6 month by one parasitic plant on a single 1-year-old host. Damage could be severe in a young plantation wher bare soil, full sun, and ready acces to hosts could foster attacks by several parasites. The pathogenic potential of this genus, especially o *A. setacea, A. tenuifolia, A. purpurea,* and *A. fasciculata,* is great because of their tolerance for a variety of hosts and their widespread distribution.



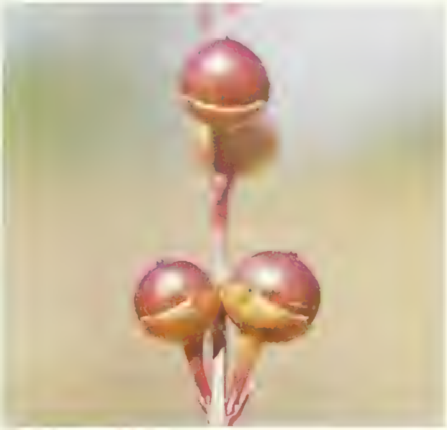
Agalinis aphylla showing flower and stalk.



Agalinis aphylla/Leafless gerardia

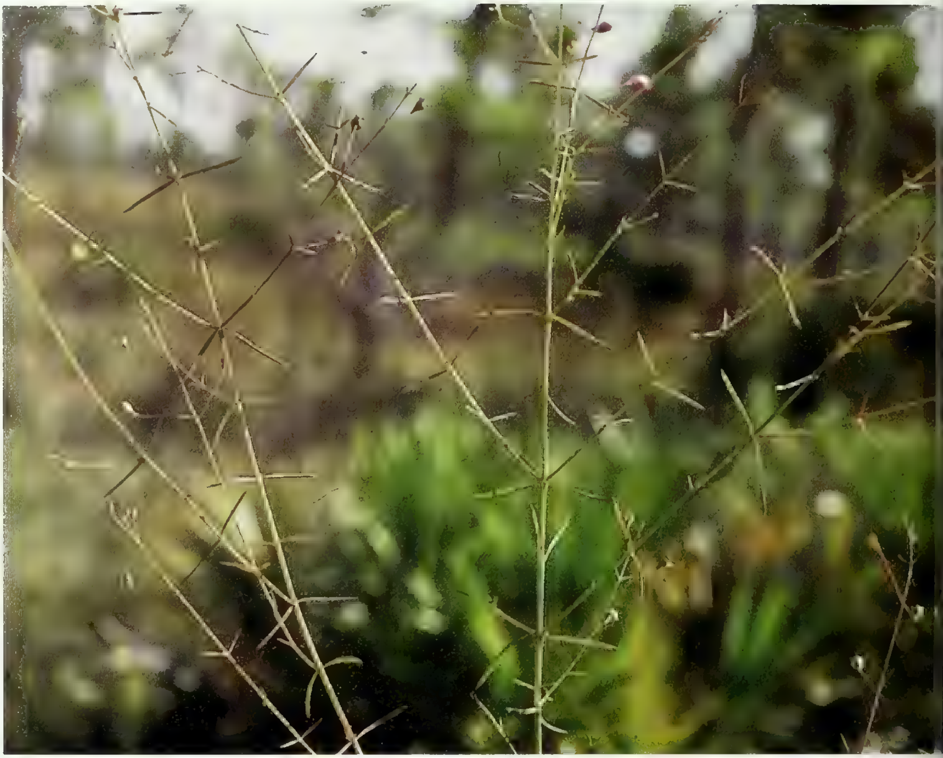
Leafless gerardia is one of the rarer species of *Agalinis*. Its habitat is restricted to pine savannas of the Atlantic and Gulf Coastal Plains where large populations are noticeable in late fall with their large, showy corollas borne on wiry, leafless stems. It is abundant only in recently burned areas.

Little is known about the host selection of the leafless gerardia, as its parasitism was only recently documented.



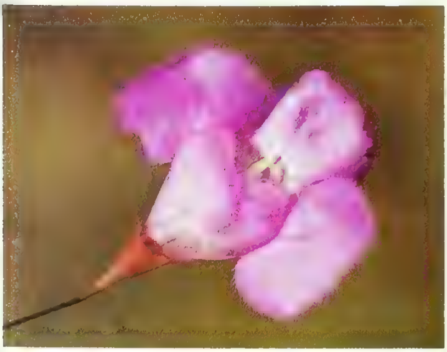
Capsules showing calyx.

ANNUAL. STEMS: up to 1 m tall, seldom branched below the top half, ridges present. LEAVES: absent, represented by small, appressed scales. FLOWERS: up to 2 cm long; bottom lobes are not at right angles to tube; wooly within the throat.

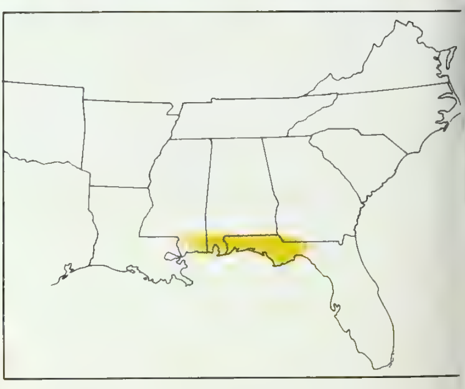


Agalinis divaricata/Gulf gerardia

This species grows only in low, open, longleaf pine communities on the Gulf Coastal Plain of Alabama and Florida. It is recognized by its conspicuously flattened corollas and downward pointed lower leaves. Like *A. filicaulis*, nothing is known concerning its host range.



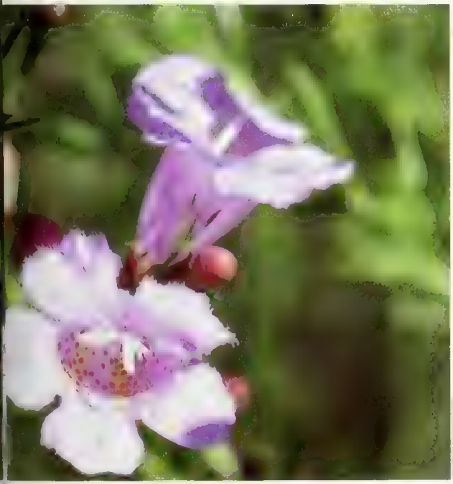
Flower showing flattened corolla.



ANNUAL. STEMS: up to 0.5 m tall, regularly branched. LEAVES: up to 1.7 cm long, 1 cm wide, larger leaves pointing down. FLOWERS: 1.5 cm long, the entire corolla strongly flattened in one plane and lacking guidelines, the upper lobes arched forward over the mouth of the corolla.

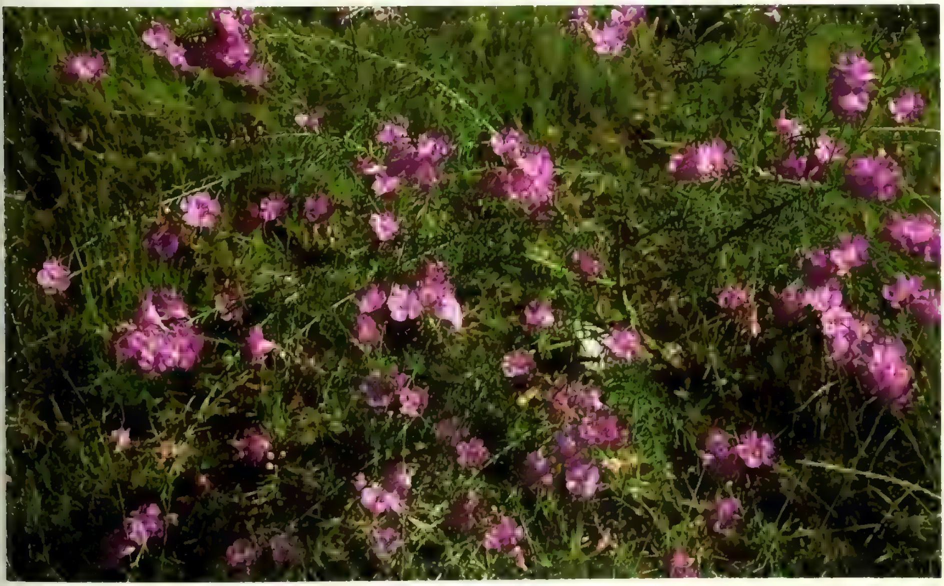
Agalinis fasciculata/Fascicled gerardia, beach gerardia

This is one of the tallest species in the genus. It has a wide geographic range, but is most common on the Coastal Plain. It is one of the more weedy species of *Agalinis* and often forms large populations of a hundred or more plants. The big, light-purple flowers are attractive. The common name is derived from the bundles of leaves (actually short, leafy branches) found at the base of the larger leaves on the stems. The host selection of *A. fasciculata* appears to be broad and without preference for any particular species. The haustoria are among the largest in the genus.

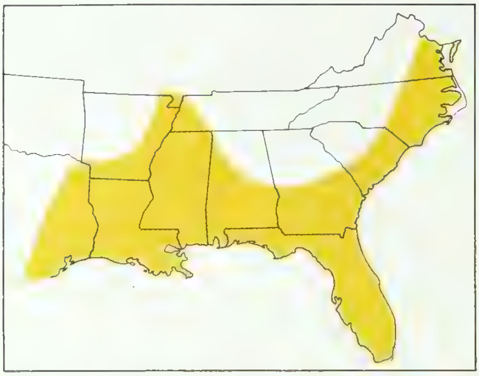


Flower

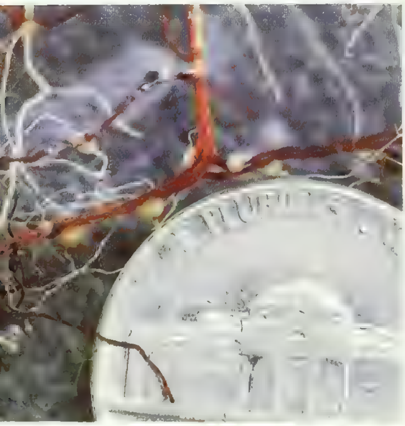
More herbarium and experimental work is needed to determine the taxonomic status of *A. fasciculata.* The taxonomic differences between it, *A. purpurea*, and *A. virgata* are not always clear. We treat *A. virgata* and *A. fasciculata* as a single species, *A. fasciculata.* These differences may be a matter of descriptive semantics. Several botanists recognize plants generally resembling *A. fasciculata* but with stiffly erect stems and fewer hairs on the stem and leaves than *A. virgata. Agalinis purpurea* may be distinct enough to warrant specific status, although it often intergrades morphologically with *A. fasciculata.*



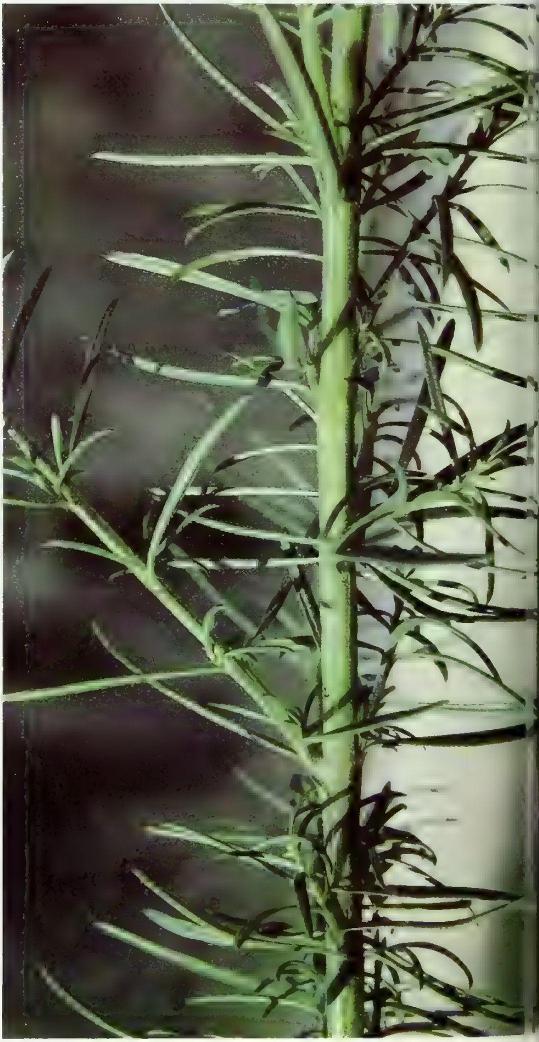
A large, much branched specimen of *Agalinis fasciculata.*



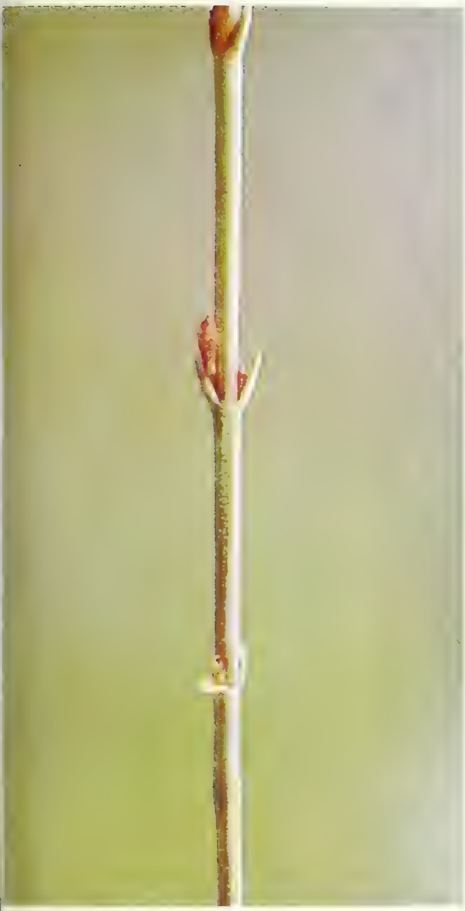
ANNUAL. STEM: up to 2 m tall, young (green) portions of stem scabrous; seldo branched at base; most branches arise from upper portion of stems. LEAVES: u to 3 cm long, 2 mm wide; younger leave somewhat hairy. FLOWERS: 2 cm wide lobes approximately equal, at right angles to the corolla tube, throat with two yellow lines and conspicuous dark purple spots.



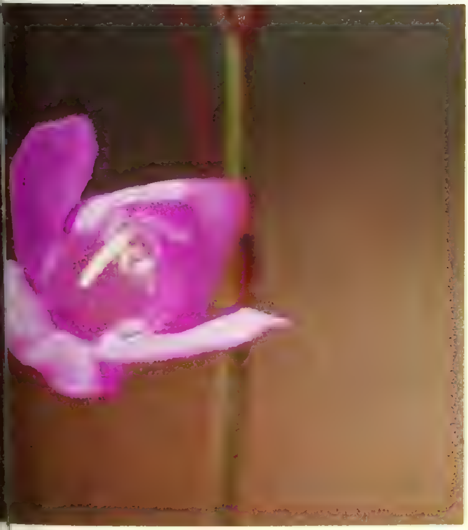
Haustoria.



"Fascicles" of leaves.

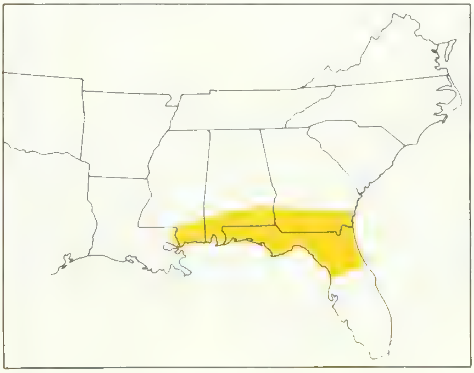


Agalinis filicaulis stem showing small, slightly divergent leaves.



Agalinis filicaulis/ Slender-stemmed gerardia

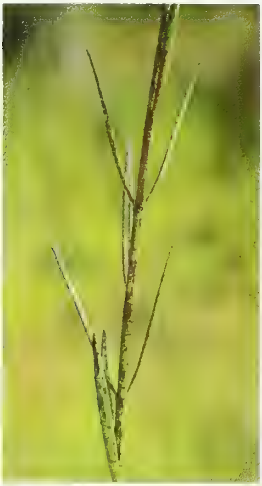
Both the leafless gerardia and this species grow in savannas on the Gulf Coastal Plain and may appear similar at first sight. But *Agalinis filicaulis* is much more branched, and has less crowded flower stalks than *A. aphylla*. The two are readily distinguished from each other by floral characters. Unfortunately, little is known about this plant.

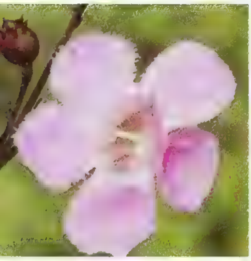


ANNUAL. STEMS: up to 0.3 m tall, very slender, irregularly branched, each branch terminated by two or three flowers. LEAVES: very small, reduced to bracts; which, unlike *A. aphylla*, are slightly divergent from the stem. FLOWERS: small, 1 cm at longest measurement, the two lateral lobes of the corolla parallel with the tube, the upper lobe reflexed over the mouth of the corolla, no yellow lines in throat.

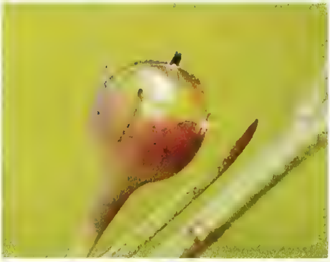
Flower showing prominent lateral corolla lobes.

Mottled stem with leaves.





Corolla.



Immature capsule with calyx.

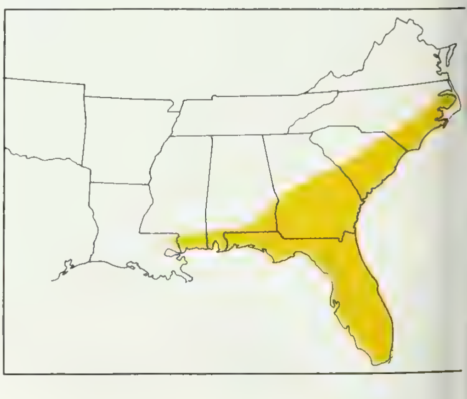
Agalinis linifolia on Blackgum.

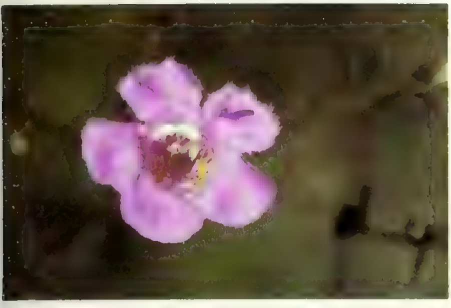
Agalinis linifolia/Perennial gerardia

This parasite is restricted to moist sites on the Atlantic and Gulf Coastal Plains. It is most commonly found at the margins of cypress pools, in shallow ditches, and in depressions in pine savannas.

Data on hosts are preliminary but perennial gerardia appears to favor species such as baldcypress that grow in moist areas.

PERENNIAL: rhizome long and narrow. STEM: up to 10 cm tall, fleshy, mottled with purple. LEAVES: up to 4 cm long, 2 mm wide, fleshy. FLOWERS: have five lobes of approximately equal size and shape, at right angles to the corolla tube no yellow guidelines in the corolla, purpl dots abundant.

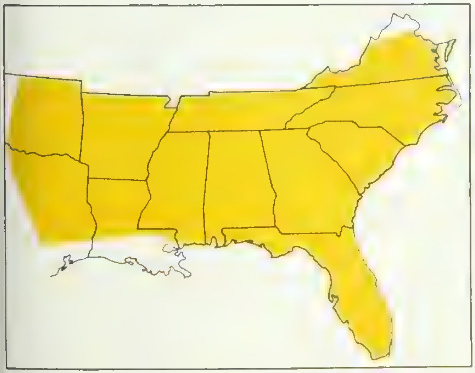




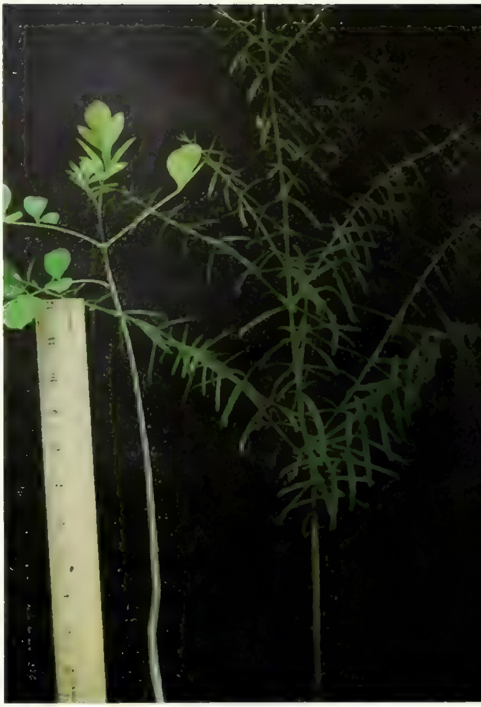
Agalinis purpurea/ Purple gerardia

Agalinis purpurea is one of the most common gerardias in the South, and is found in large numbers along roads and in other open, disturbed sites. Superficially, it may be confused with *A. fasciculata*, particularly in flower structure. However, *A. purpurea* has broader leaves, poorly developed fascicles (if any), and typically is well branched.

In culture, individuals of the purple gerardia will flower and set seed without attachment to any host. Such plants are usually smaller than plants with hosts. This autotrophic behavior has not been reported from nature.

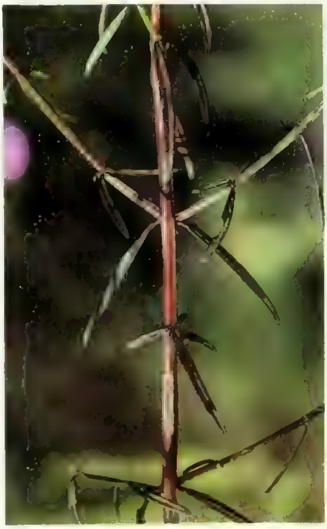


ANNUAL. STEMS: up to 1 m tall, usually much branched, older branches have distinct ridges. **LEAVES:** up to 3.5 cm long, 2 mm wide, scabrous. **FLOWERS:** similar to *A. fasciculata*.



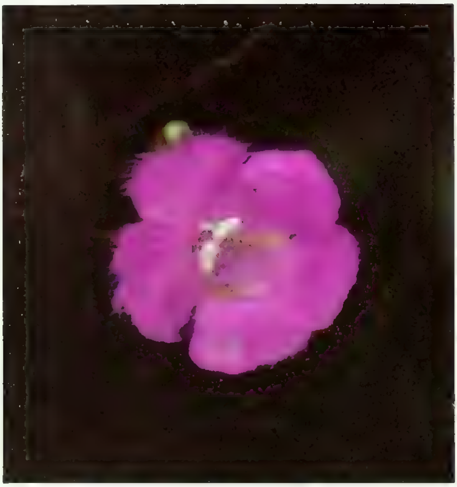
Agalinis purpurea on Green ash.

The host range of *A. purpurea* is one of the largest in the genus. In our pot studies, *A. purpurea* parasitized all 19 species (see Appendix III). Eight hosts had over 200 haustoria.



Stem and leaves.

Corolla



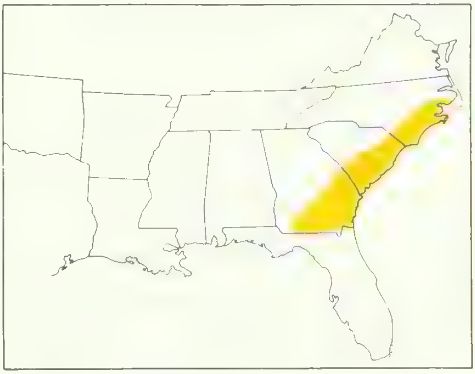
Agalinis tenella/ Slenderleaf gerardia

This species favors weedy habitats along the Atlantic Coastal Plain. It is often abundant in dry pinelands and on roadbanks. *Agalinis tenella* is one of three species that may be easily confused. *Agalinis setacea* is another Atlantic Coastal Plain species that prefers disturbed habitats. It has a range extending furthe north and west than *A. tenella.* The floral and vegetative features of these two species are very much alike. Both have bristle-like leaves and two prominent yellow guidelines in the corolla. But *A. setacea* is a larger plant overall, and has corollas twice as large as *A. tenella.*

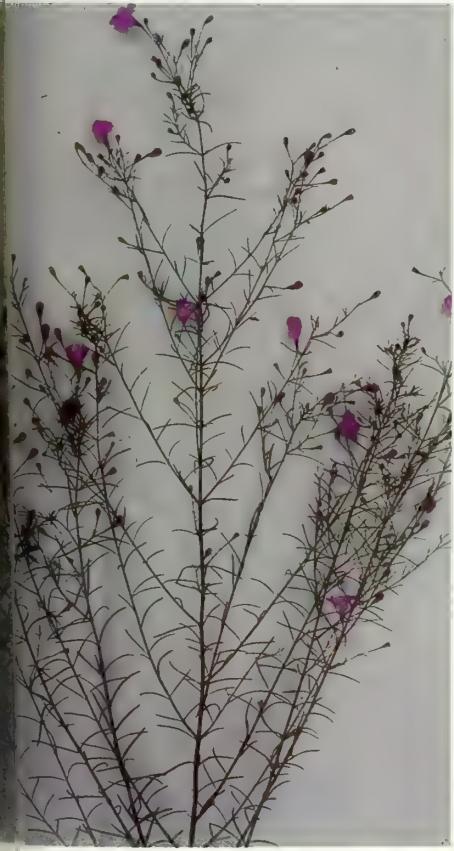
Group of ***Agalinis tenella***

The third species, *A. obtusifolia*, grows in pine savannas, but may also be found in disturbed habitats. It is a small plant, like *A. tenella*, and seldom reaches over 60 cm in height. Its leaves are broad (up to 1.5 mm wide) relative to the size of the plant. *Agalinis obtusifolia* is distinguished from *A. tenella* by a sparse branching pattern, ridged stem, and lack of yellow guidelines in the corolla. A peculiar feature of *A. obtusifolia* is the occasional production of flowers directly on the lower stems of older plants.

We have experimental data on host selection for *A. setacea* only (Appendix III).



ANNUAL. STEMS: up to 0.5 m tall, profusely branched. LEAVES: up to 3 cm long, very narrow and bristle-like. FLOWERS: 1.2 cm wide, 1.5 cm long; lobes of approximately equal size and shape, at right angles to the corolla tube; upper throat of the tube hairy; throat has two yellow lines and numerous dark purple spots.



enella

Leaves

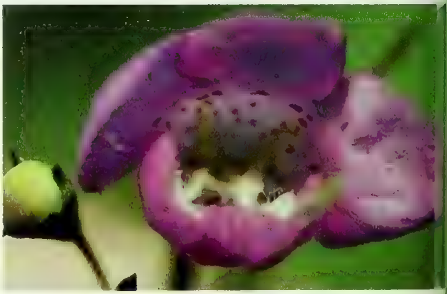
Agalinis tenuifolia/ Slender gerardia

Agalinis filicaulis, A. tenuifolia, and *A. divaricata* have distinctive flowers in which the upper lobes of the corolla are arched forward, partially closing the throat. Of these, *A. tenuifolia* is the most widely distributed, being found throughout eastern North America. It is usually a much-branched plant, and quite variable in size. *Agalinis tenuifolia* and *A. setacea* may appear similar in growth form, but *A. setacea* has very narrow leaves and a conspicuously hairy corolla throat.

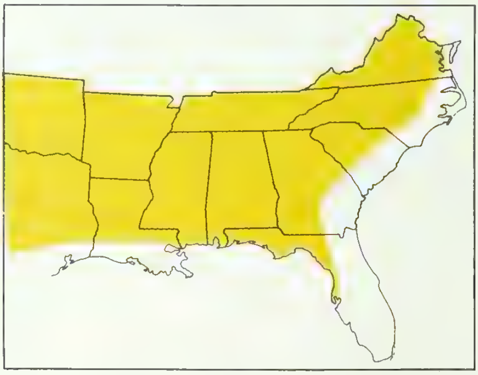
Slender gerardia commonly grows in disturbed sites, including clearcut areas. Large populations may also be found growing at the margins of ditches and in other wet or moist habitats.

This species is a vigorous parasite. It formed haustoria on all 19 commercial species (Appendix III). Of these, three plants formed over 1,000 haustoria on their hosts. No clear host preference was shown, although hardwood species supported more parasitic attachments than pines.

Agalinis tenuifolia on sycamore.



Corolla showing upper two lobes shorter than the remaining three.

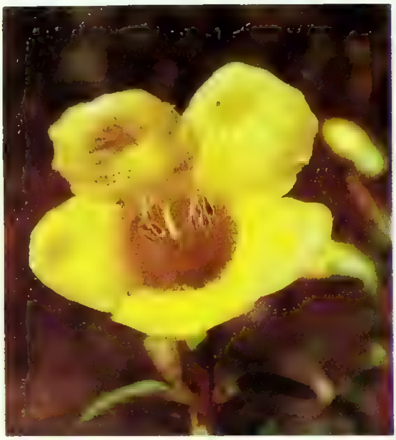


ANNUAL. STEMS: up to 1 m tall, profusely branched. LEAVES: up to 1.5 mm wide, largest leaves at right angles to stem. FLOWERS: corolla lobes not equal, the lower three at right angles to the tube, the upper arched forward partially covering the stamens, yellow lines in throat.

Aureolaria/False foxglove

The false foxgloves are some of the most widely distributed root parasites in the South. The common name derives from the resemblance of the flower shape to that of the common garden foxglove (genus *Digitalis*). All species have large showy flowers similar in size and shape, which open early in the morning and usually drop from the plant by late afternoon. Like *Agalinis*, the flowers are borne with only two open per flowering branch at one time. Except for occasional populations of *Aureolaria pedicularia*, all species flower from late summer to mid-fall. The leaves are opposite and some are deeply lobed in all species but *A. laevigata*. False foxgloves prefer open, sunny areas. The haustoria of these plants are large and numerous, and often form self-attachments.

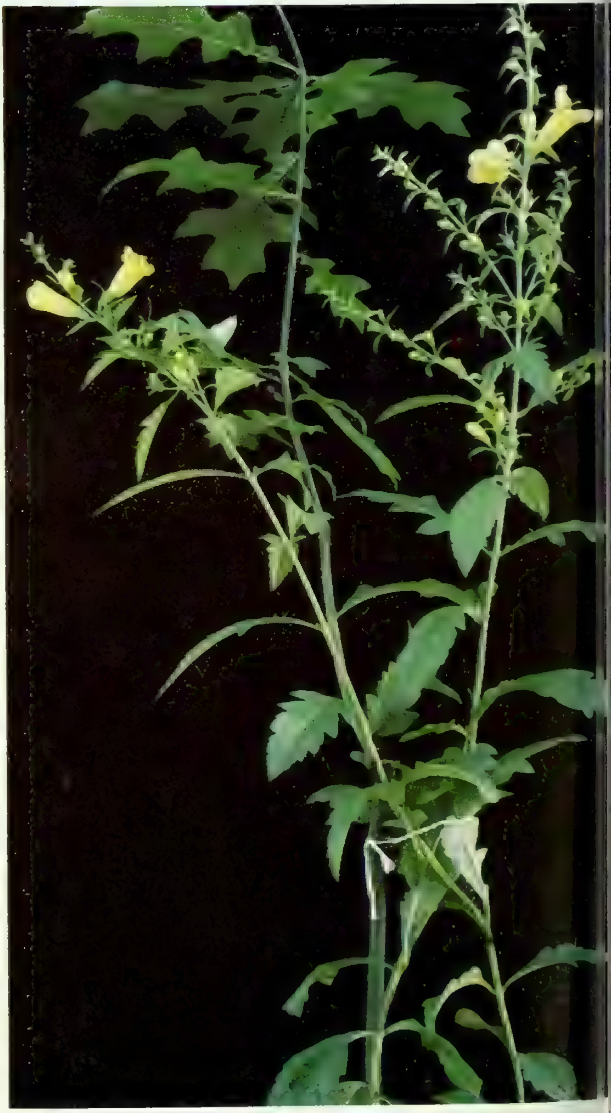
Corolla



Aureolaria flava/Large false foxglove

This is the tallest of all member
the genus and the most widesp
of the perennial species. It usua
flowers in mid-autumn through
most of its range, but may occa
ally flower in late October in pa
of Florida. Large false foxglove
grows in various open, dry habi
including disturbed sites. Large
populations are often found at
margins of oak stands. In Georg
and Florida it is sometimes four

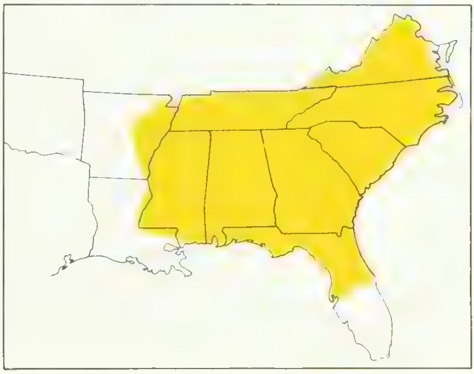
Aureolaria flava on Shumard oak.

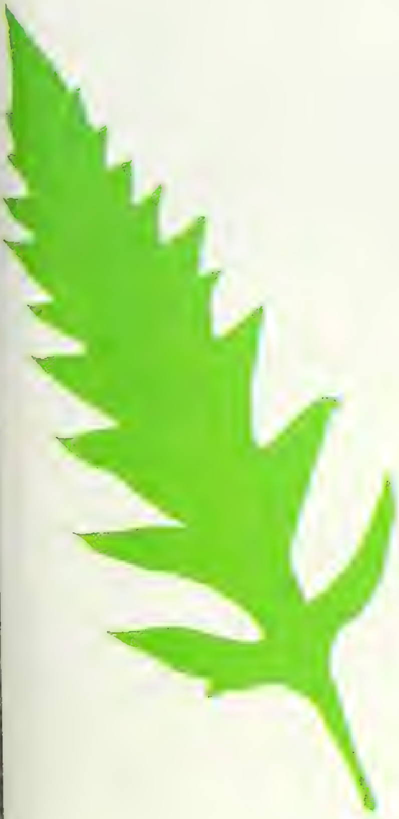


pen areas in scrub oak-palmetto
ds.

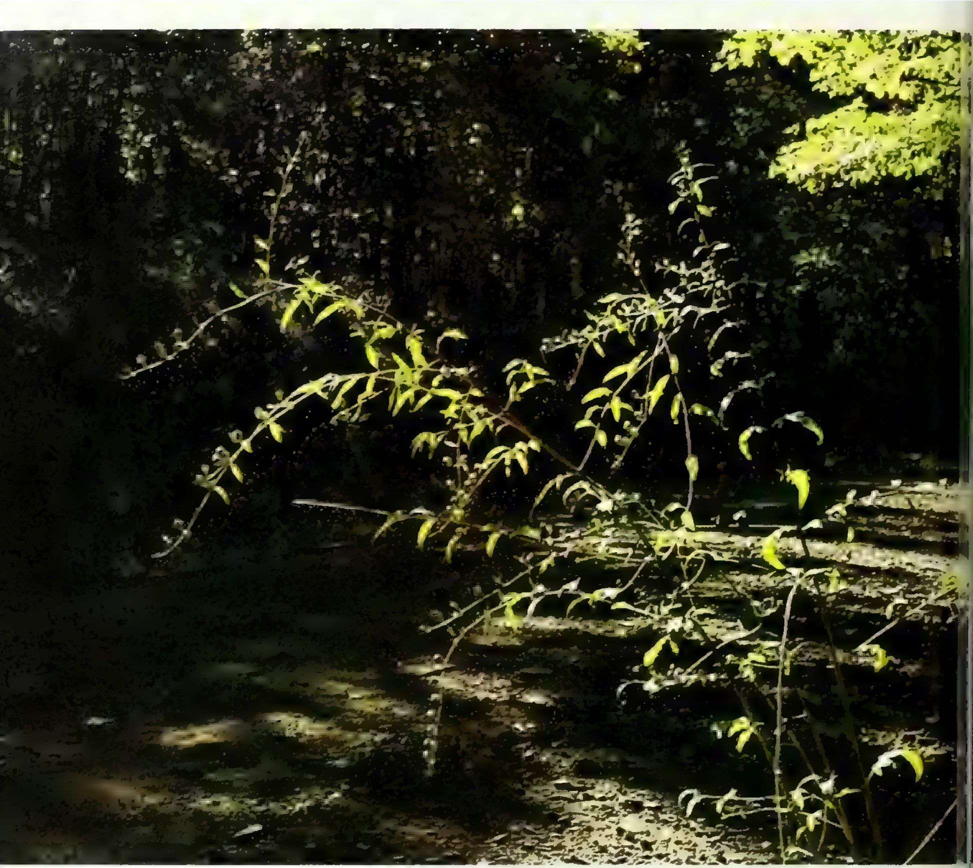
haustoria of *A. flava* are up to
m across (the largest in the
phulariaceae), and will readily
oung roots and stunt older
s. Previous researchers have
sidered this parasite to be re-
ted almost exclusively to the
e oak group (Pennell 1935). In
study, *A. flava* formed large
storia on 18 of 19 commercial
ies (Appendix III).

PERENNIAL. STEMS: 1 to 2.5 m tall, sparsely branched, glabrous, hollow. **LEAVES:** basal, 7 to 15 cm long, 1.5 to 5 cm wide, lower deeply lobed, the upper (including the reduced leaves of the inflorescence) entire.

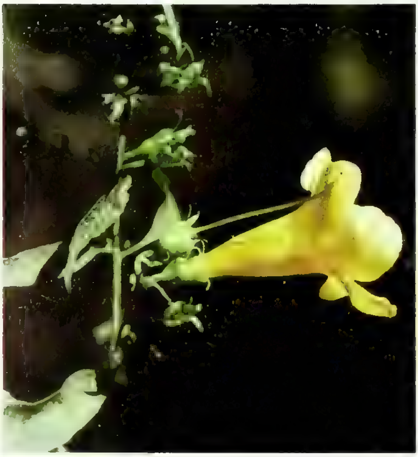




Silhouettes of various leaf forms.
Left—Basal leaf
Right—Reduced leaves associated with flowers



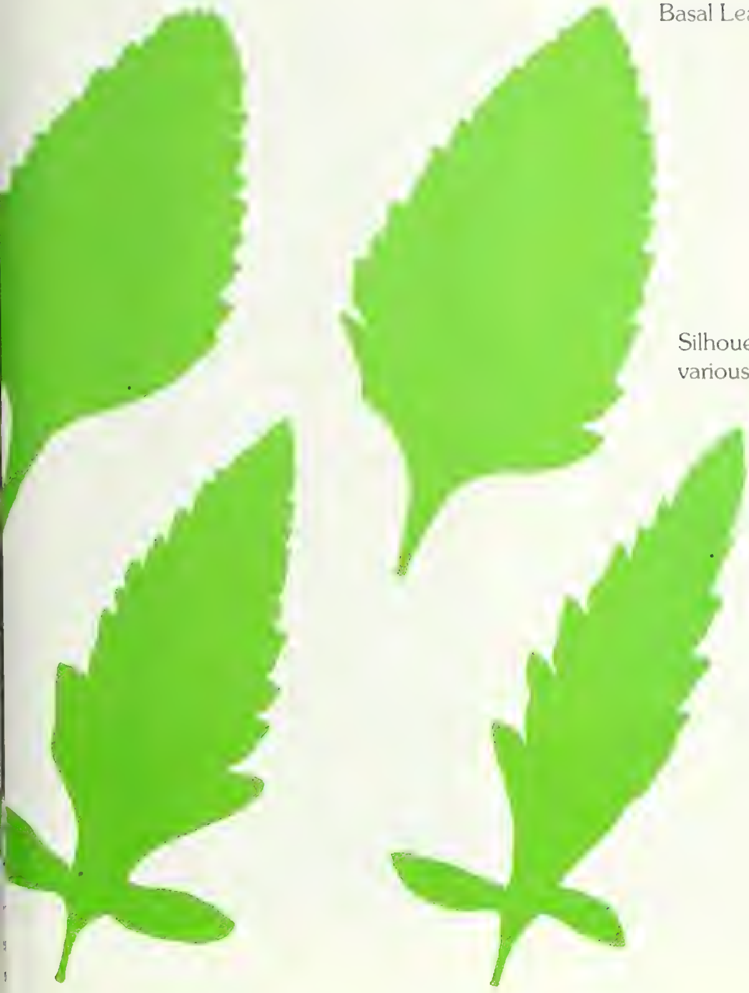
Larger plants of ***Aureolaria grandiflora*** have spreading branches.

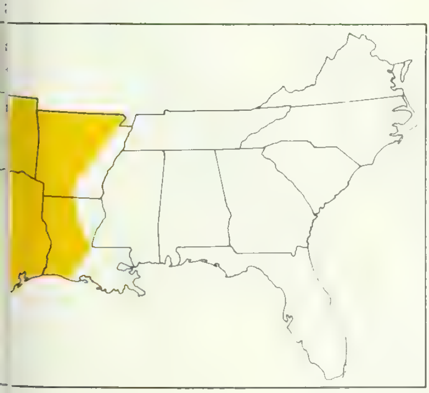


Flower

Aureolaria grandiflora/Show false foxglove, big-leaf oaklee

Aureolaria grandiflora is comm the Ozark and Ouachita Mount The selection of hosts, like thos all perennial species, was once thought to be very narrow and restricted to white oaks. Howev our work indicates that *A. gran flora* will parasitize many wood herbaceous species. It grows in oak woods on rocky or sandy s


Basal Leaves
Silhouettes of various leaf forms.
Upper Leaves

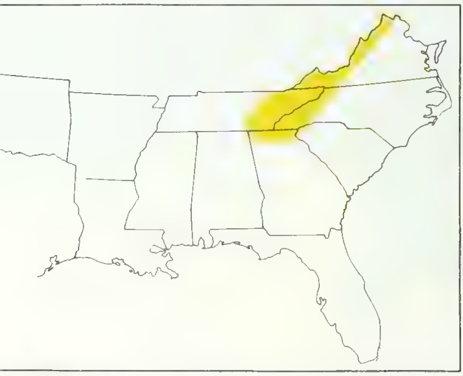


PERENNIAL. STEMS: 1 to 2 m tall, profusely branched, lateral branches often as long as the main stem, hollow. LEAVES: basal, 5 to 12 cm long, 1.5 to 4 cm wide, with scattered stiff hairs; those of westernmost plants (Ouachita Mountains) tend to be deeply lobed; those of more easterly plants are not; upper leaves of all plants have prominent lobes.

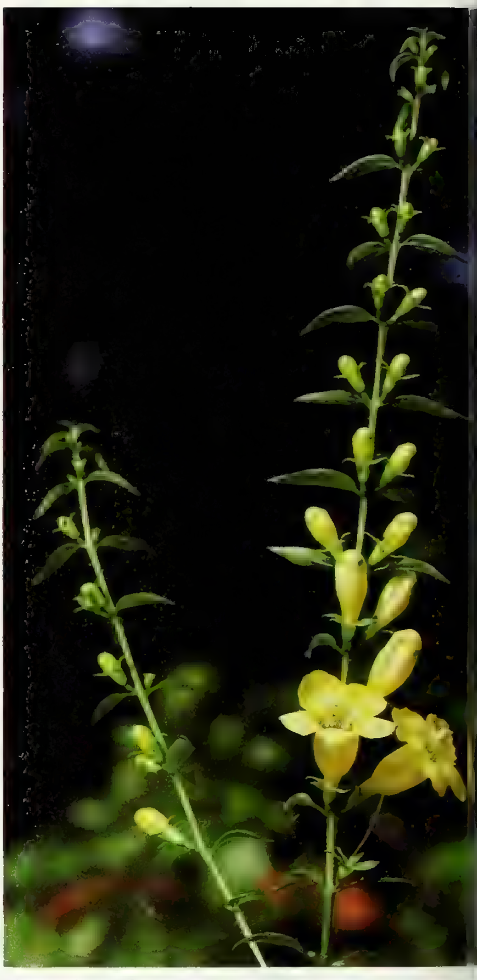
Aureolaria laevigata/Smooth false foxglove

Aureolaria laevigata is restricted to the southern Appalachians where it may form large populations at the margins of oak woods and in disturbed sites such as road and power line rights-of-way. Superficially, it can be confused with *A. flava* but is readily distinguished by its much smaller size and narrower, unlobed leaves.

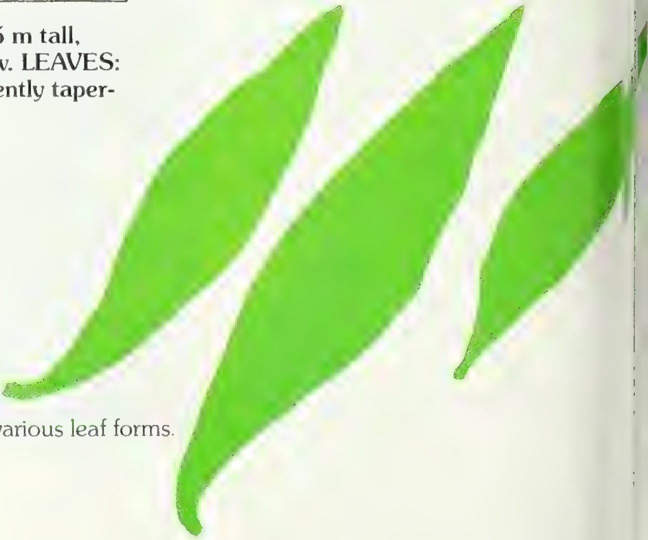
Little information was available on the host selection of this species except for the early observations of Pennell (1935), who stated that it parasitizes white oaks. In our tests it formed haustoria on 13 of 19 species (Appendix III).



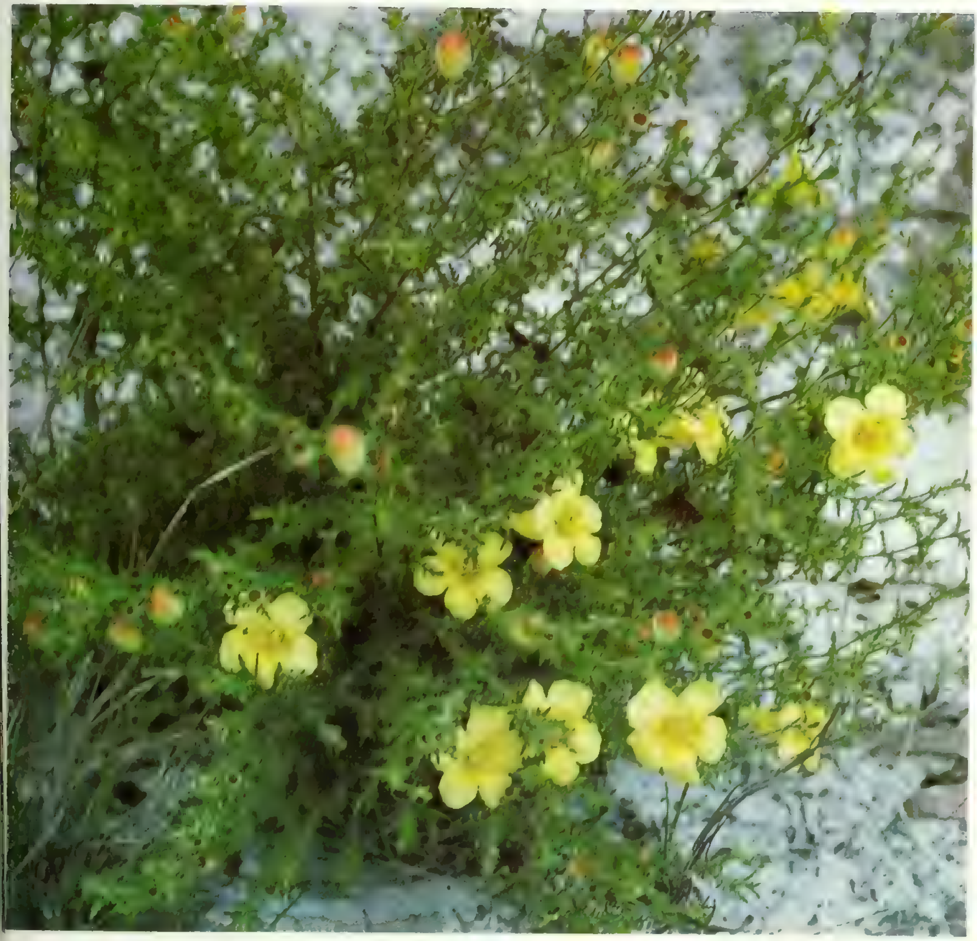
PERENNIAL. STEM: up to 0.5 m tall, very sparsely branched, hollow. **LEAVES:** up to 6 cm long, 2 cm wide, gently tapering to a narrow point.



Aureolaria laevigata

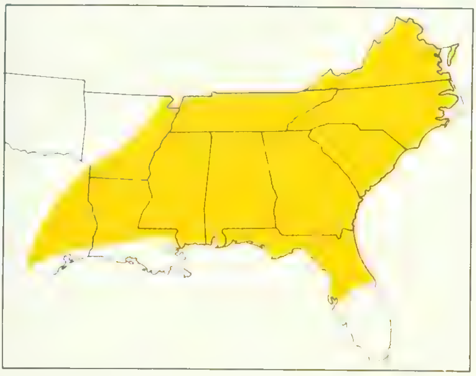


Silhouettes of various leaf forms.



Aureolaria pedicularia/ Fernleaf false foxglove

There is disagreement among botanists as to how these plants should be treated taxonomically. According to some, those plants with pectinate (comb-like) divisions of the leaves, and abundant glandular hairs on the upper portions of he plant, should be treated as a distinct species, *A. pectinata.* n our work, we have found that here is a more or less continuous ange of variation in regard to these haracters. More northerly plants esemble *A. pedicularia.* These plants have broader leaves and



ANNUAL or BIENNIAL: entire plant covered with glandular hairs. STEMS: 1.5 to 2 m tall, solid, much branched (especially when growing in full sunlight), lateral stems arch upward. LEAVES: up to 6 cm long, 2.5 cm wide, with four to six lobes or prominent teeth.

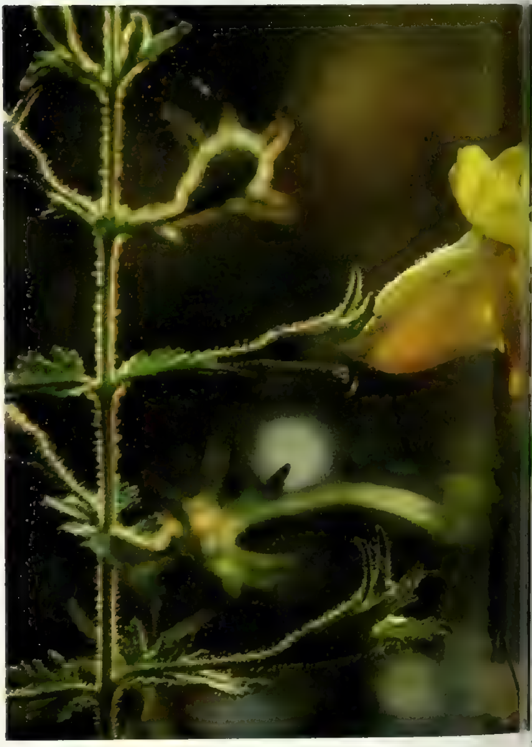
Leaves from southern plants

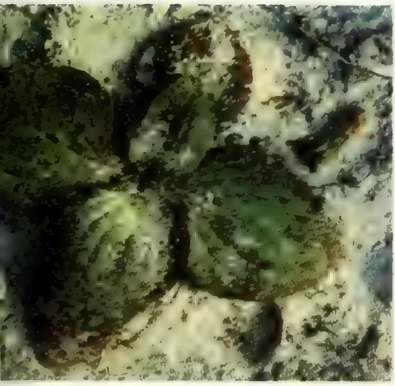
fewer glands, although plants fitt both descriptions may be found throughout the East. Consequen we consider these plants one species, *A. pedicularia*, until a more thorough taxonomic study is completed.

Glands are a distinctive feature c this species. They are especially active on hot, sunny days. Handl the plants at this time will leave a fragrant yellow resin on the hanc that soon oxidizes to a black gun The secretion of the glands may the parasite in its transpirational pull on host tissue. Only this spe and *Seymeria cassioides* have ab dant glandular hairs.

Aureolaria pedicularia occurs throughout eastern North Ameri and may be found in almost any open, dry habitat. It is most abundant in the sand hills of the

Flowering branch showing glands.





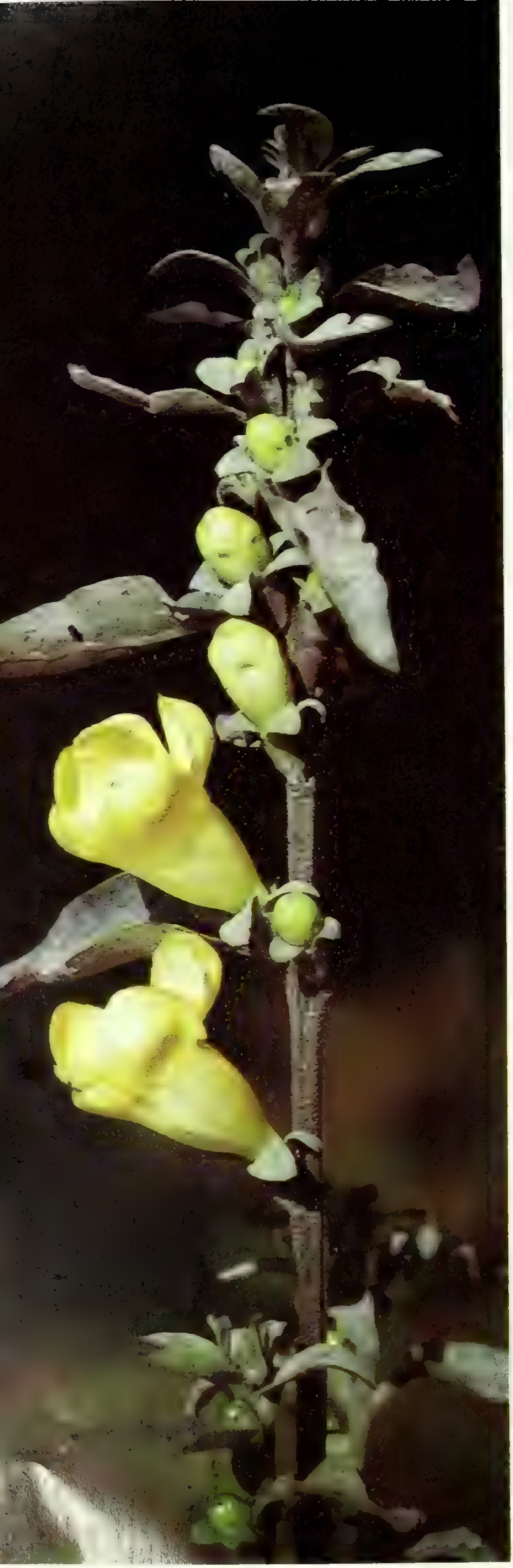
linas and the sandy flatwoods
rthern Florida.

ıctivities of man have contrib-
to its spread. It is often found
ge numbers on road banks and
r line rights-of-way and other
bed areas. Because of its
rence for such habitats and its
ic seed production, it has great
gical potential as a forest
ation pathogen.

Leaves from northern plants.

The life history of *A. pedicularia* is variable depending on where it is growing. In the North, it is a biennial which produces a rosette in late summer, overwinters in this stage, and bolts the following spring. In central Florida and perhaps elsewhere in the Deep South, it is an annual. When this occurs, *A. pedicularia* flowers around May.

Like all species in the genus, the flowers of *A. pedicularia* are large, showy, and last for only one day. The flowers have a distinct fragrance, noticeable early in the morning. The host selection of *A. pedicularia* has been studied extensively (Pennell 1935). It was once thought to have a narrow host selection, and to require attachments to trees of the black oak group for maturation. In nature, haustoria will sometimes form on non-oak species but not without some haustoria of the same plant being attached to a black oak. In pot studies, *A. pedicularia* formed 41 haustoria on water tupelo as well as 198 on eastern cottonwood. One thousand two hundred ninety-two haustoria were found on shumard oak and 402 on southern red oak, both of which are in the black oak group.

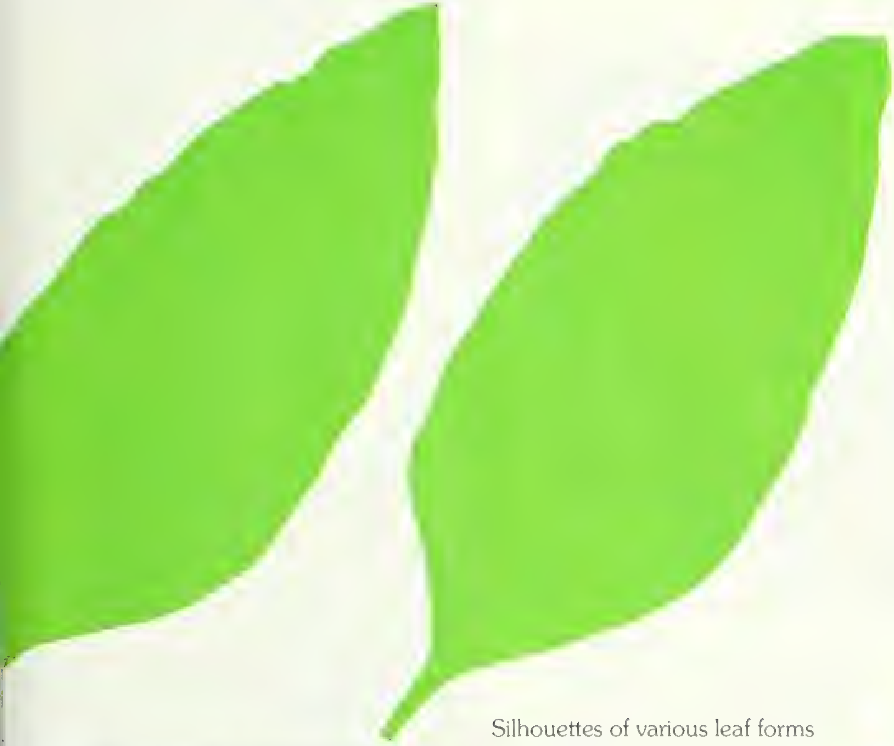


Aureolaria virginica/ Downy false foxglove

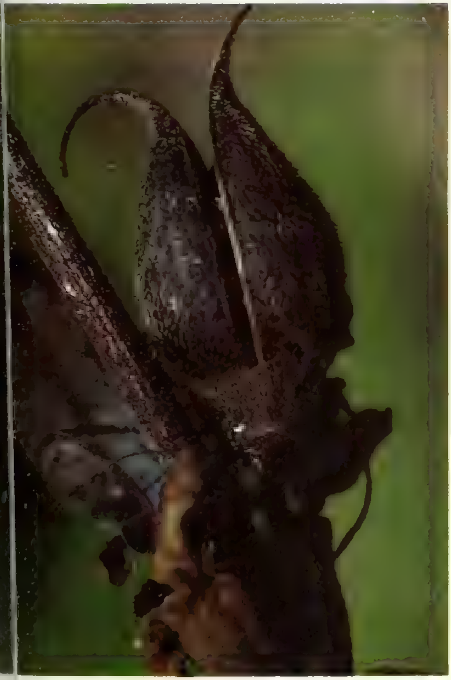
A wide-ranging species found throughout the South. It is the distinctive of all the perennial species and is identifiable any ti of year by its densely hairy stem and leaves and is the only speci with hairy fruits. It grows on dry open, sunny margins of oak wo road banks, and clearings.

Like other perennials in this ge it is thought to parasitize trees c the white oak group, but pot stu showed haustoria formation on but one of the 19 species testec (Appendix III).

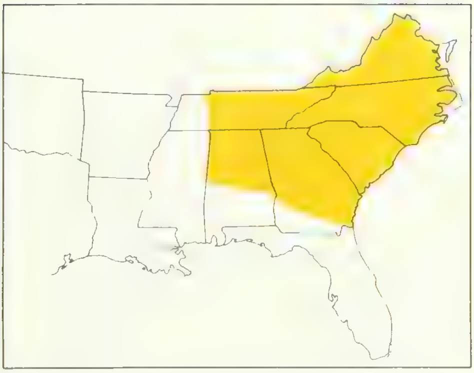
Aureolaria virginica



Silhouettes of various leaf forms

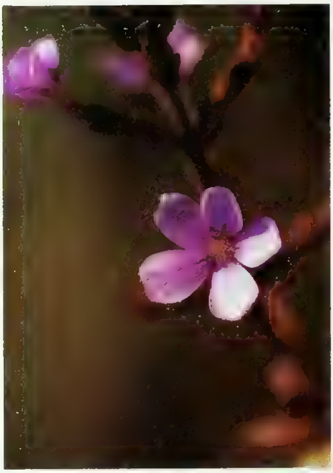


Open capsule with persistent hairs.



PERENNIAL. STEMS: up to 1.5 m high, rarely branched. LEAVES: up to 10.5 cm long and 4 cm wide, basal leaves usually have two prominent lobes.

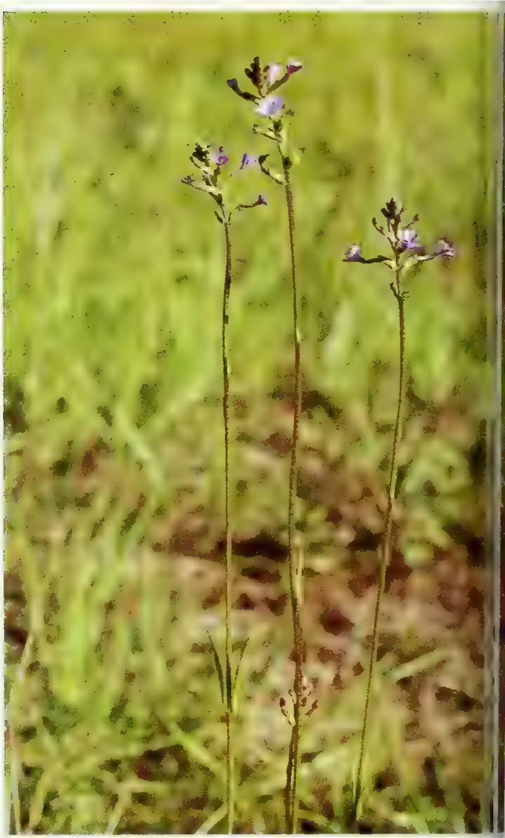
Flowers are nearly symmetrical.



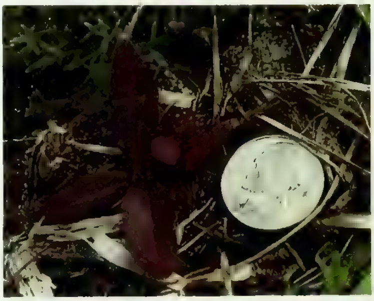
Buchnera americana/Bluehearts

Bluehearts is found throughout most of the southern and central United States but is most abundant in central and southern Florida. It prefers moist, sandy soils and full sun and may occur in large numbers after logging of low flatwoods. This and related species will mature without ever attaching to a host plant. *Buchnera americana* is often described as a perennial, but our field and greenhouse studies clearly show that it is a rosette-forming biennial. In this booklet we recognize only one species, but other workers treat an additional species, *B. floridana* based on slight differences in the venation of the basal leaves. Plants of southern Florida tend to have three veins in the larger leaves and corollas that are larger and redder than those of northern plants.

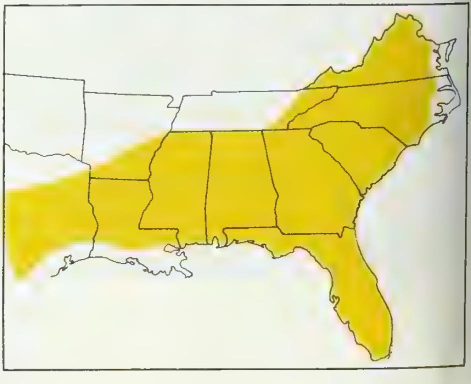
BIENNIAL. STEM: up to 1 m tall, LEAVES: clustered near the base, rough to the touch, usually three-veined. FLOWERS: reddish-purple to blue. CAPSULES: 1 cm long, cylindric with very thick compartments. SEEDS: less than 1 mm long, shiny, black.



Buchnera americana



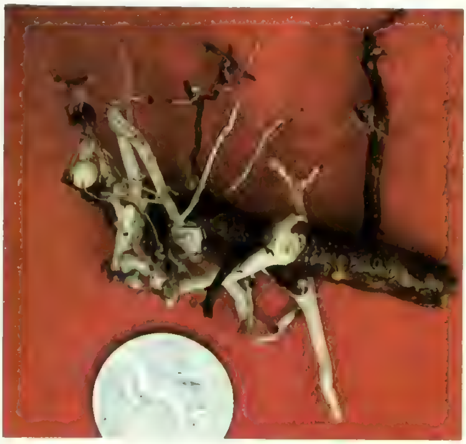
Rosette



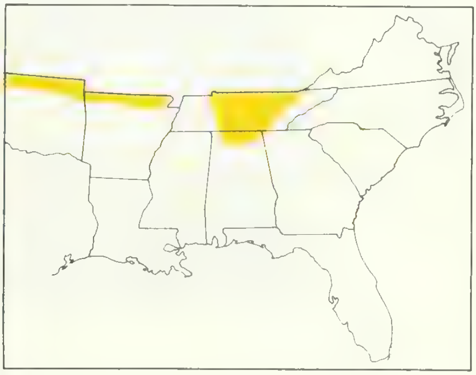
Dasistoma macrophylla/ Mullein foxglove

The common name of this limestone-loving plant is appropriate because the small, bright yellow flowers resemble the flowers of the common mullein, *Verbascum thapsus*. *Dasistoma* has a broad geographic range, but is most common on the Cumberland Plateau, in central Missouri, and other limestone areas. It is often found on stream banks and in openings in alluvial forests. Our studies show that *Dasistoma* is a rosette-forming biennial. Seedling establishment takes place in late summer. One plant produces several hundred capsules or more and is capable of supplying thousands, perhaps millions of seeds. In terms of numbers and size of haustoria, this species is the most vigorous in the family. When the roots of a mature parasite are excavated, one finds hundreds of short roots, each terminated by a haustorium that penetrates the host.

Intertwined roots of host and parasite with numerous haustoria.

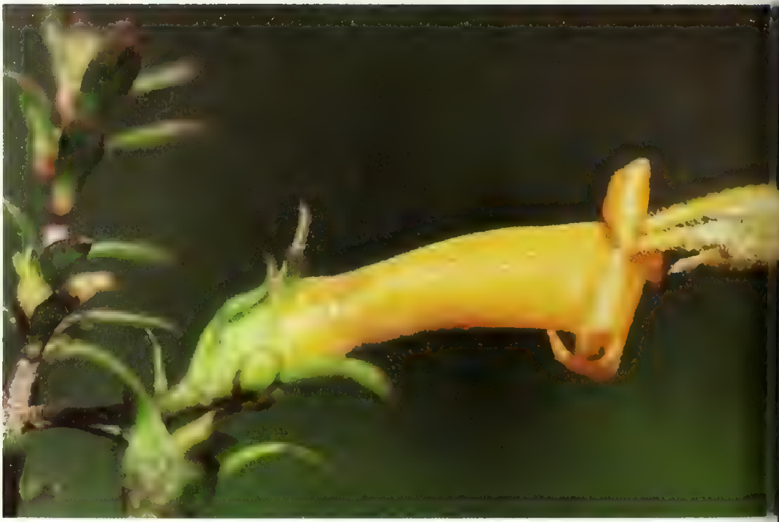


A large specimen of ***Dasistoma macrophylla*** with fruit.



BIENNIAL. STEM: up to 1.5 m tall, profusely branched. LEAVES: large, up to 20 cm long, 5 cm wide, the lowest leaves have a few deep lobes, upper leaves tend to be entire. FLOWERS: up to 1 cm long, about as wide, inside of the flower densely hairy.

Ste



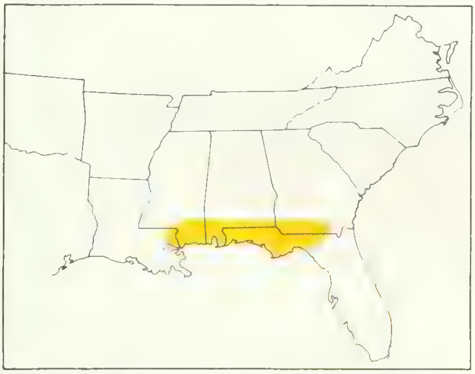
Macranthera flammea/ Macranthera, orange blackherb

This is perhaps the most beautiful of all southern root parasites, and one of the largest. *Macranthera* is a rosette-forming biennial. The seeds germinate in the spring to form a rosette that bolts the following year. Abundant, bright orange flowers, which are reportedly pollinated by hummingbirds, are produced at
ends of the abundant branches
fall. *Macranthera* is a Gulf Coas
endemic and prefers the open,
sunny margins of gum swamps.
Like *Dasistoma*, this species is a
particularly vigorous parasite. A
one excavation in northern Flor
hundreds of haustoria were for
on a single young blackgum roc

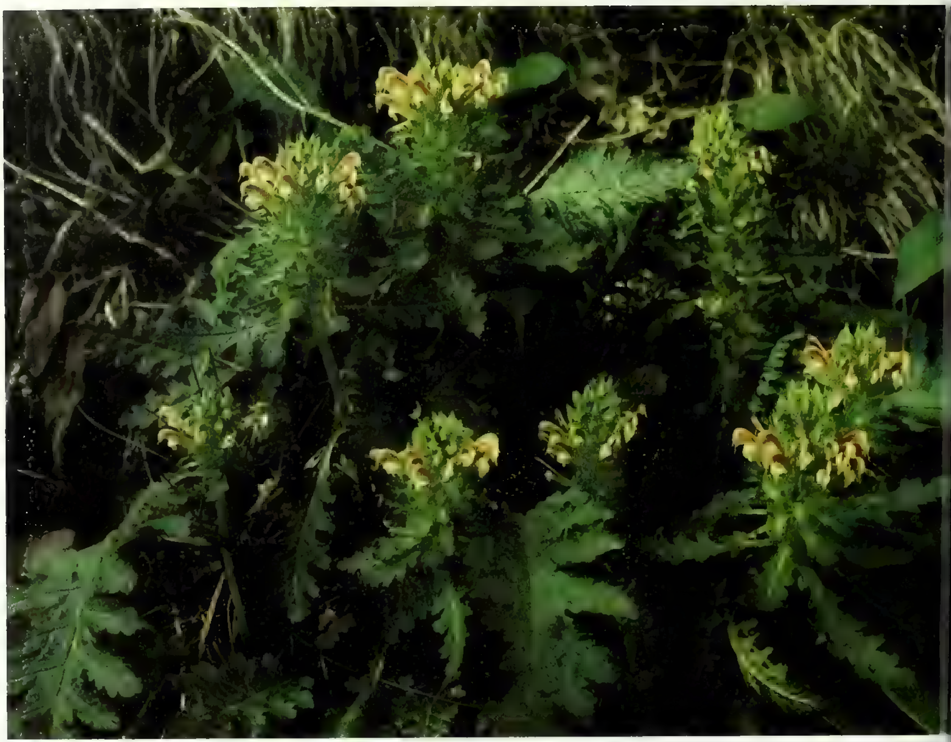
thera flammea on yellow - poplar.

Young fruits with persistent styles.

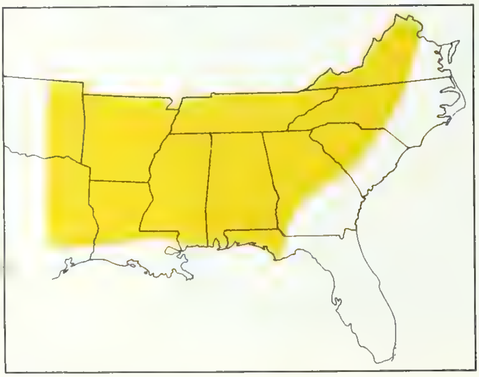
BIENNIAL. STEM: up to 3 m tall, much branched. LEAVES: deeply divided, up to 8.5 cm long, 3 cm wide, falling from older portions of stem. FLOWERS: bright yellow-orange, tubular, 4 cm long. CAPSULE: hairy with persistent style.



In our pot studies, *Macranthera* formed haustoria on white pine and other trees with which it is not associated in nature (Appendix III). Thus, it has the potential of parasitizing a large number of species.



Pedicularis canadensis



PERENNIAL: spreads by whitish rhizomes. STEMS: unbranched, up to 20 cm tall. LEAVES: deeply dissected, 10 cm long, 4 cm wide, most of the leaves clustered at the base of the stem. FLOWERS: borne in dense heads, two-lipped, 2 cm long, 0.5 cm wide. CAPSULE: 1 cm long, enclosed by green sepals. SEEDS: about 10 per capsule, 5 mm long, brown.

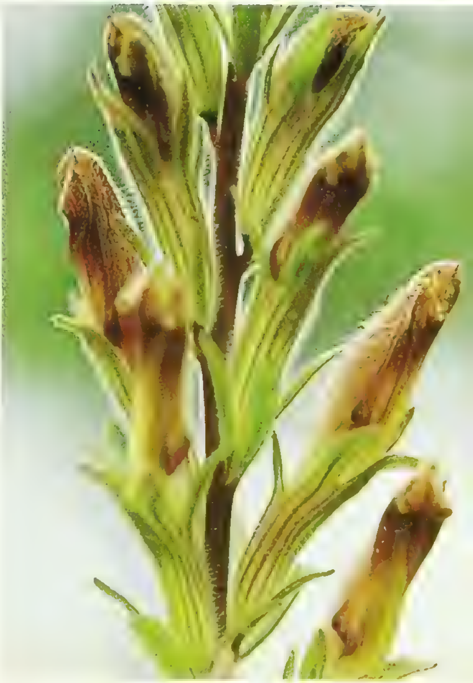
Pedicularis canadensis/ Common lousewort, wood beton

All above-ground parts of this plan are covered with broad hairs that were once thought to harbor lice, hence the name, lousewort. This i one of the more common plants o the southern Appalachian forests, but it is found throughout the South. Few parasitic figworts tolerate as much shade as wood betony, although it apparently needs an open canopy to become established. There is considerable variation in the color of the flower They range from yellow to reddis brown.

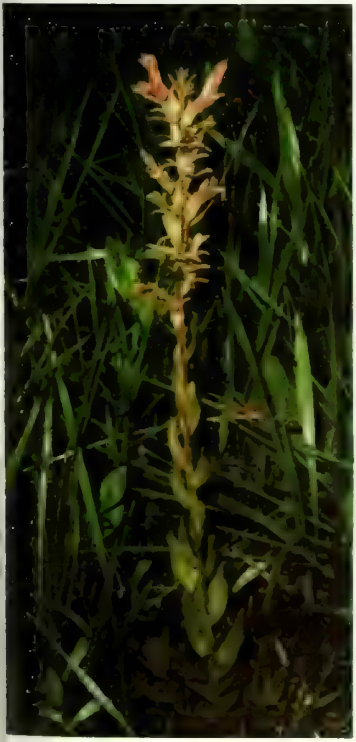
Piehl (1963) studied the host sele tion of *P. canadensis* in Michigan and recorded attachments to 80 species of vascular plants in 35 families. Many of these hosts were trees.

Schwalbea americana/Chaffseed

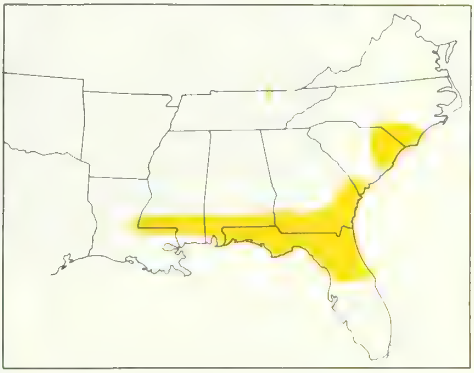
Chaffseed is the rarest parasitic seed plant in the South and is currently known from two populations in South Carolina (each with less than 25 plants) and one population in the New Jersey pine barrens. It grows in pine savannas and other open, sunny habitats. Its rarity is not caused by its preference for a specialized host. We have been able to grow it with several tree species. Because of this rarity, there is little chance that chaffseed could become a serious problem. *Schwalbea* flowers in the spring and produces seed in the early summer. Each seed is long and narrow and enclosed in a loose-fitting sac-like structure that provides the basis for the common name, chaffseed.



Flowers



Schwalbea americana



PERENNIAL: entire plant copiously covered with soft hairs. **STEMS:** up to 8 dm tall, unbranched. **LEAVES:** alternate, without a leaf stalk, up to 4 cm long, 1 mm wide. **FLOWERS:** borne in the axil of reduced upper leaves, 15 mm long, 7 mm wide, yellow to purple. **CAPSULE:** enclosed by the persistent sepals, cylindric, up to 10 mm long. **SEEDS:** 6 mm long, yellowish, narrow.

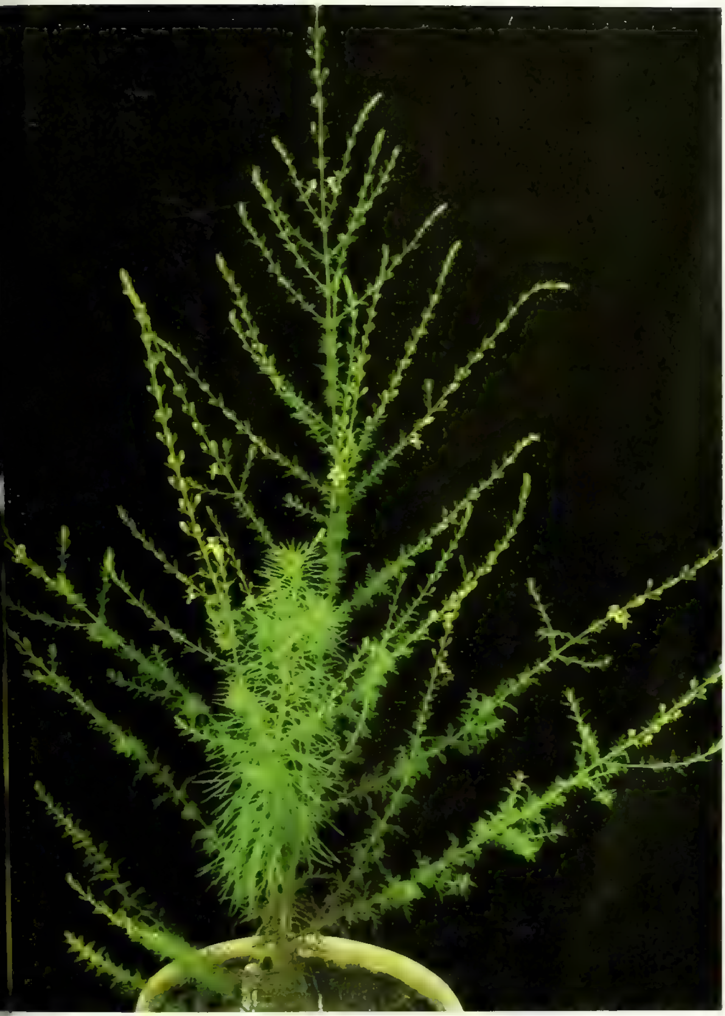
Seymeria/Seymeria

In terms of damage to commercial species, this is the most important genus of native root parasites in the South. Damage to pines by *S. cassioides* is well documented, although Mann and others (1969) were the first to report damage to any commercial species by a native root parasite. Two sympatric species occur in the South but are distinctive and easily recognized. Both produce abundant, small, yellow flowers in late summer and early fall. Each flower lasts for only one day before falling from the plant. The flowers of this genus have an unusual type of anther opening, a small pore rather than a long slit.

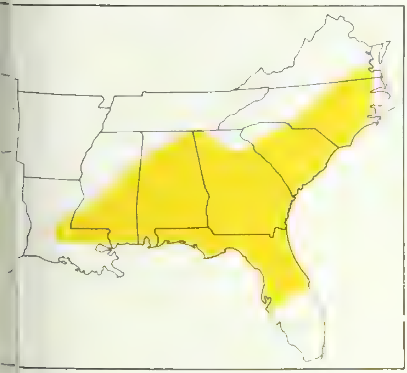
Leaves showing arra

Seymeria cassioides/Senna seymeria

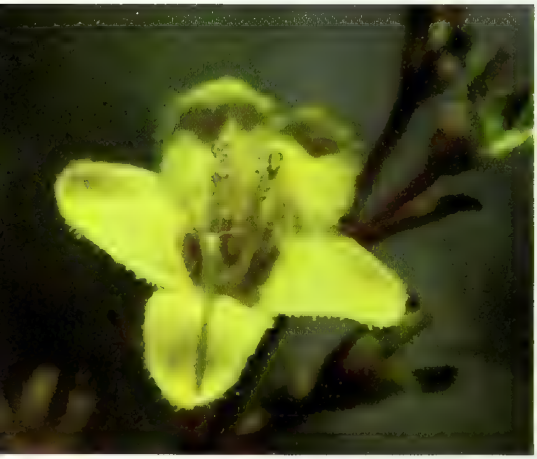
This is one of the few root parasite which exhibits any host specificity. It will produce normal-sized plants only when grown with pines. This host requirement enhances its pathogenic effect because there is no sharing of the parasitic impac by other species nearby. Senna seymeria is readily grown from see without any pretreatment.



Seymeria cassioides on Ocala sand pine



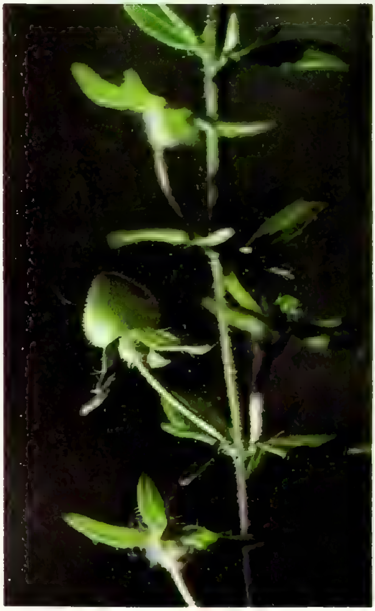
ANNUAL. STEMS: up to 1 m tall, much branched, entire plant covered with glandular hairs. LEAVES: finely divided into linear segments; in the field each segment gives the impression of being an individual leaf. FLOWERS: 1 mm long, bright yellow with brown marks near the ovary, outside of flower not hairy. CAPSULES: 5 mm long, shiny brown when mature.



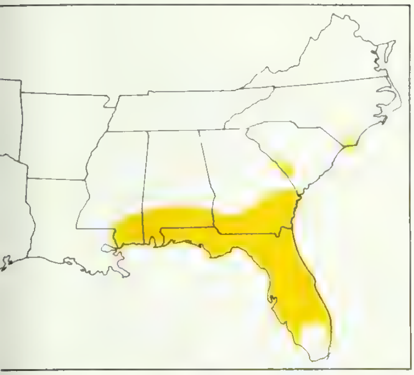
Flower

Seymeria pectinata/Comblea seymeria

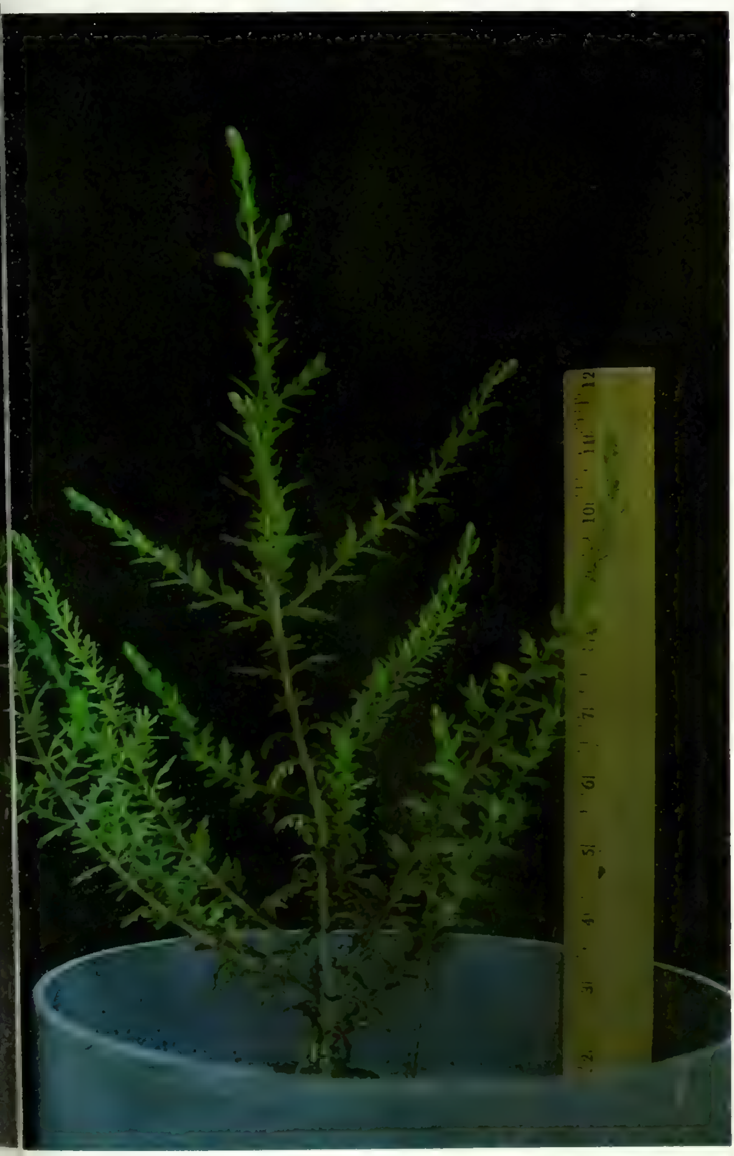
Combleaf seymeria is much mo restricted in its distribution than senna seymeria and also has a much broader host range. It pr drier sites (such as turkey oak-s oak woods) than *S. cassioides,* on rare occasions both may be found growing together. We ha found no evidence of hybridiza between the two species. In ou studies *S. pectinata* parasitized yellow poplar, blackgum, water tupelo, pecan, sweetgum, greer american sycamore, and four d ferent pines (Appendix III). The species are not present in the communities where *S. pectinat* grows, which indicates a patho potential, especially on drier sit in the Deep South.



Young fruits covered with hairs.



ANNUAL: entire plant covered with stiff nonglandular hairs. STEM: up to 75 cm tall, widely and stiffly branched, the longest branches arising near the base of the plant. LEAVES: deeply divided with segments broader than 1 mm. FLOWERS: solid yellow, 1 cm long, hairy on the exterior. CAPSULE: ovoid, 5 mm long, covered with glandular hairs.



Seymeria pectinata on pecan.

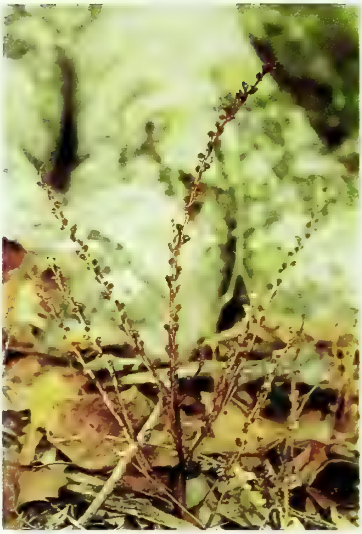
Orobanchaceae
(Broomrape Family)

Orobanchaceae (Broomrape family)

Unlike all the other families considered so far, broomrapes would be recognized as parasites at first glance. They lack chlorophyll entirely and are usually succulent and herbaceous with the above-ground parts lasting only one growing season. Several species are serious pathogens on a variety of food crops in the Mediterranean region, the Middle East, and central Asia, where they cause great economic losses. The species of the South are rather benign although careful studies of the effect of these plants on their hosts have not been carried out.

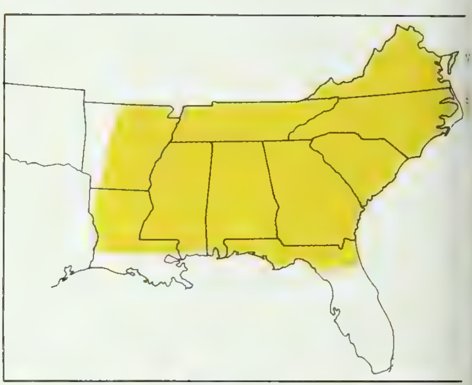
There are three genera in the eastern United States: *Orobanche*, *Conopholis*, and *Epifagus*. Species of *Orobanche* are rather rare and difficult to locate. They were not included in our culture study at the request of USDA Plant Protection and Quarantine because some have the potential of becoming serious parasites of crop plants such as tobacco and tomato.

Both *Epifagus* and *Conopholis* (each with a single species in our region) are widespread and are good examples of parasites very selective for hosts. We were unable to germinate seed of either *Epifagus* or *Conopholis*. *Epifagus*, as the name implies, will grow only on the roots of the American beech, *Fagus grandifolia*. *Conopholis* has been found only on the roots of members of the red oak group. Because both attack forest species, they are included in this study even though no experimental data are available.



Plant in fruit.

ANNUAL: arising from a swollen, bulb-like base from which short, stiff hook-like roots arise. STEM: up to 0.5 m tall, usually much branched. LEAVES: absent, represented by minute scales. FLOWERS: 6 mm long, 2 mm wide, white with brown; cleistogamous flowers are often present, most commonly at the base of the plant. CAPSULE: 5 mm long, 2 mm wide.

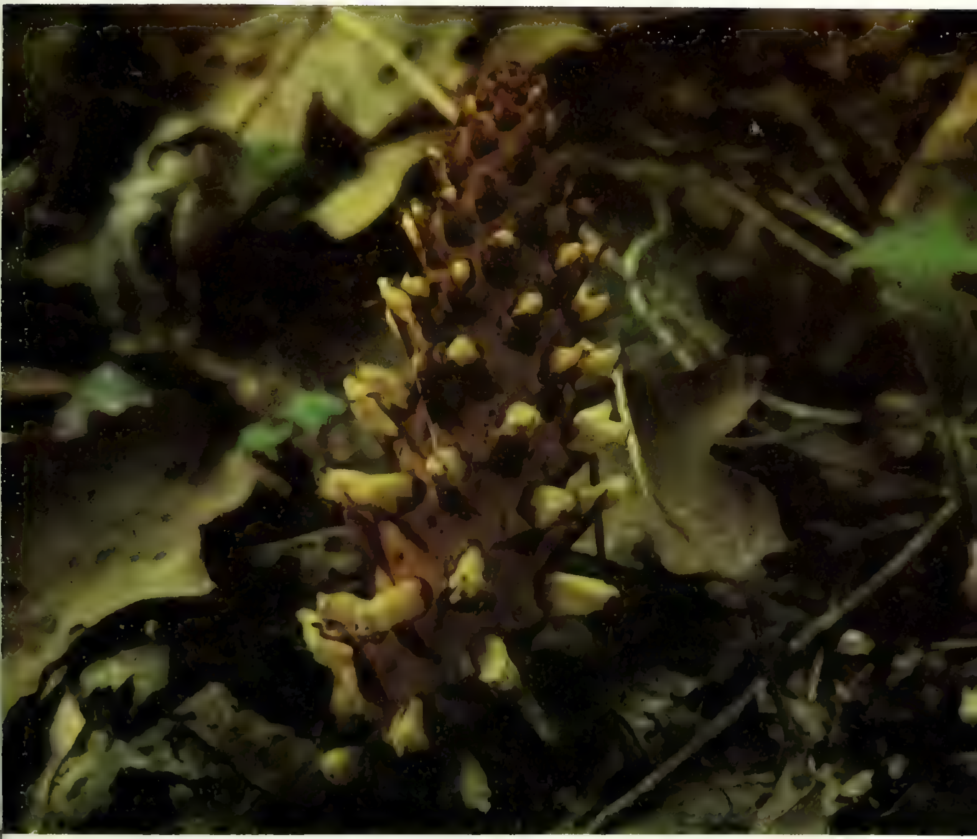


Epifagus virginiana/Beechdrops

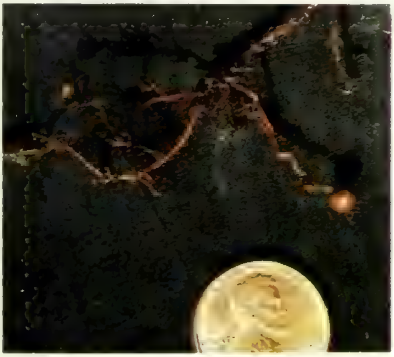
Epifagus may be found anywhere American beech grows. While the ranges of host and parasite are sympatric, not all beech trees in a given stand are parasitized by beechdrops. The entire plant is pale brown with purple stripes and blotches. Beechdrops flowers in the autumn. The flowers, like the plants, are inconspicuous. Within a few weeks of flowering, the capsules split open to release dust-like seeds. They apparently open in such a way as to form a splashcup for dispersal of seeds by rainwater. We have determined that there are about 14 million beechdrops seeds in one pound.

Ripe fruit showing numerous dust-like seeds.

A large population of ***Epifagus virginiana*** at base of old beech.



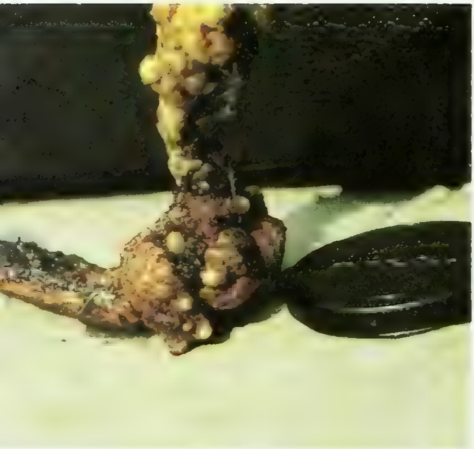
Conopholis americana, just past flowering.



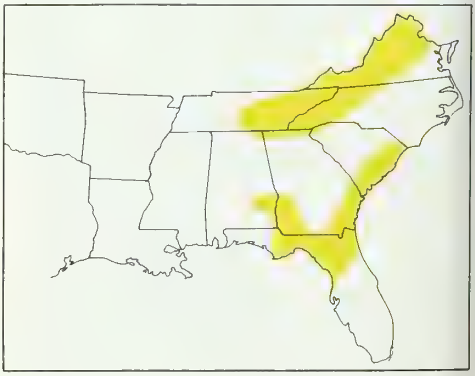
Seedlings

Conopholis americana/ Squawroot, cancer root

Conopholis is widespread throughout the South but is less common in the western regions of the South. It is distinctive and is easily recognized at almost any time of year. Very little is known about its life history. The seeds apparently take several years to germinate. In one of the few instances where *Conopholis americana* has been grown from seed, at the University Botanic Garden in Copenhagen, 8 years elapsed between sowing of the seeds and emergence of the flowering stalks. We found the first recognizable stage to be a swollen white growth on small oak roots. As the parasite develops it apparently stimulates host tissue growth until a gall-like mass of host-parasite tissue develops. When examined microscopically, it is difficult to distinguish between host and parasite tissue because the two tissues are so intermingled. The host root usually dies back to the gall-like growth. In spite of this damage, it has not been possible to determine growth loss or damage to the host tree. From the underground perennating structure, fleshy, yellow shoots covered with large brown scales arise in spring. Small flowers are borne from the fleshy stem. The stems and fruits are apparently an important part of the diet of bears in some areas of the southern Appalachians. The fruit is usually described as a dry capsule when mature, but the seeds appear to be ripe while the capsule is fleshy. This fleshy structure may be a means of dispersal by animals.



Host root. Parasite and host tissue.

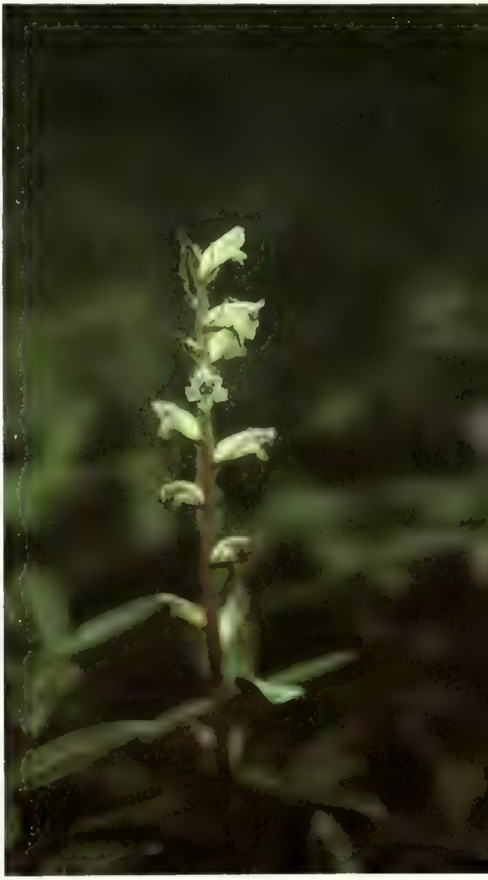


PERENNIAL: arising from an underground swollen mass on oak roots. STEMS: up to 16 cm tall, yellow, fleshy. LEAVES: absent, represented by large brown scales. FLOWERS: small, 2 cm long, two-lipped, yellowish with some purple. FRUIT: a capsule with numerous yellowish-brown, shiny seeds.

Orobanche minor/Small broomrape

This species is very rare and is apparently known in the South only from a few locations in Virginia and North Carolina. However, it could easily be overlooked since it is a very small and inconspicuous plant. It is also shade-tolerant and may grow unnoticed beneath dense vegetation. Its selection of hosts is apparently broad. Small broomrape have been recorded on legumes and other crops in Europe and the Middle East. For several years at one site in Virginia, a population has been observed parasitizing the roots of ornamental shrubs.

Unlike many of its relatives, small broomrape is not presently known to cause any serious damage although it could be considered potentially harmful. *Orobanche minor* could easily spread throughout a planting, because like all species in this genus it produces thousands of seeds per plant. Damage from such a holoparasite would be considerably greater than from an equal number of hemi-

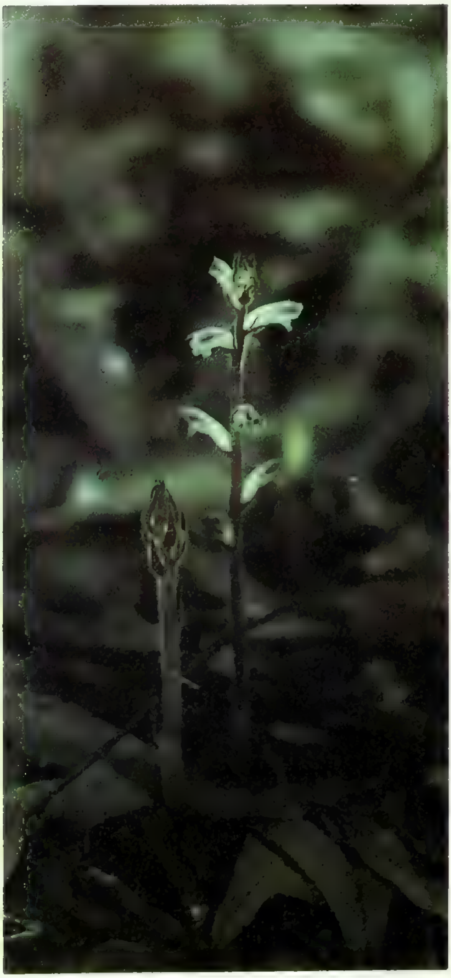


Flowering stalk.

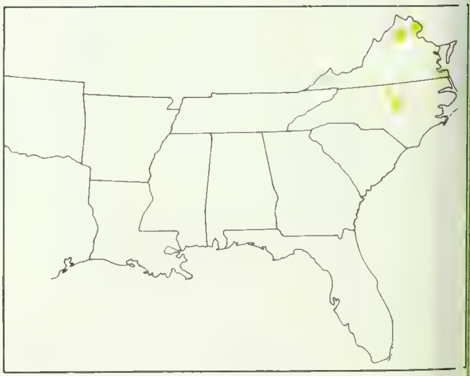
parasites because of the total dependence of these parasites on their host.

Small broomrape is easily distinguished from the more widespread native species, *Orobanche uniflora*, which has bluish-white, densely hairy stems, and solitary flowers.

Aspect and young plant of ***Orobanche minor.***



ANNUAL: seeds apparently germinating in early spring to form small, round, white seedlings on host roots. STEMS: up to 15 cm tall, fleshy, unbranched, brown. LEAVES: absent, represented by small scales. FLOWERS: up to 2 cm long, 0.5 cm wide, whitish. CAPSULE: 1 cm long, 0.5 cm wide with numerous dust-like seeds.

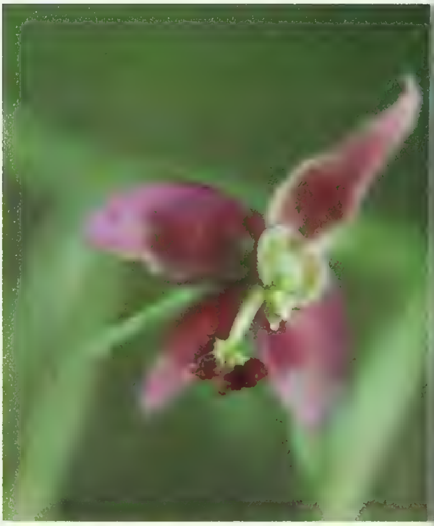


Krameriaceae

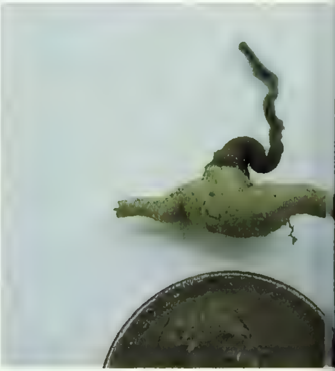
(Rattany Family)

Krameriaceae (Rattany family)

The rattany family is small (a single genus). Most species are found in the deserts of the Southwestern United States. Only one species, *Krameria lanceolata*, occurs in the Southeast, where it is restricted to deep sand ridges of the coastal rivers of Georgia and sandy flatwoods in northern and central Florida.



Flower

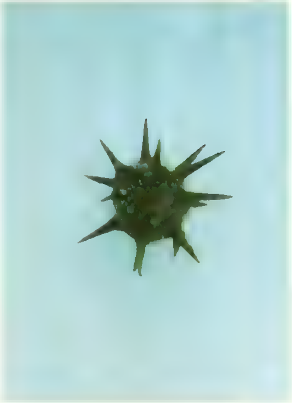


Haustorium on host root.

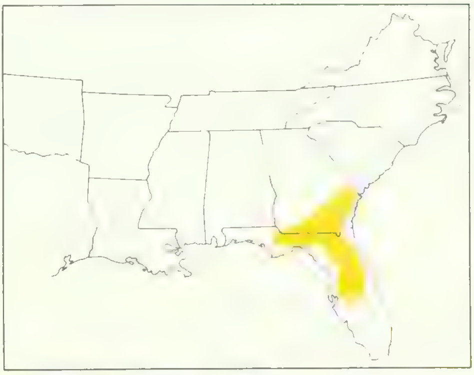
Krameria lanceolata/Sandspur

Sometimes called sandspur because of the resemblance of its fruit to a sandbur, *Krameria lanceolata* is visually unimpressive. It forms an extensive network of wiry rhizomes from which the stems arise. Large, fleshy taproots are present. The leaves are small and grayish green. Attractive purple flowers are produced in May.

Recent studies have shown that *K. lanceolata* attacks many hosts including longleaf pine, persimmon, turkey oak, prickly pear, and various grasses and forbs (Musselman 1975).



Fruit



PERENNIAL: arising from stout taproots. STEMS: up to 2 dm long, lying on the ground. LEAVES: alternate, up to 1.7 mm long, 2.5 mm wide, widest at tip, covered with long, silvery hairs, deciduous. FLOWERS: 2 cm long, purple, irregular n shape. FRUIT: 1 cm in diameter, armed with sharp prickles, resembling a sandbur, containing one seed.

A single specimen of ***Krameria lanceolata*** growing with wiregrass.

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Appendix

Appendix I
Root parasites of the Southeast

This is a list of all native root parasites that are known to occur in the states of Virginia, Tennessee, Arkansas, Louisiana, Mississippi, Alaba Georgia, Florida, South Carolina, and North Carolina. The list is bas on field work, published floras, and herbarium data. Taxonomic synor are not included. Witchweed, *Striga asiatica* (L.) Kuntze, is an introdu pathogen found in a few counties of North and South Carolina.

Name and Author	**Common Name**
Krameriaceae **(Rattany family)**	
Krameria lanceolata Torr.	Sandspur
Olacaceae **(Olax family)**	
Schoepfia schreberi J. F. Gmel.	Whitewood
Ximenia americana L.	Hog plum, tallowwood
Orobanchaceae **(Broomrape family)**	
Conopholis americana (L.) Wallr.	Squawroot, cancer root
Epifagus virginiana (L.) Barton	Beechdrops
Orobanche	
O. uniflora L.	One-flowered cancer root
O. minor Sm.	Small broomrape
O. ludoviciana Nutt.	Louisiana broomrape
Santalaceae **(Sandalwood family)**	
Buckleya distichophylla (Nutt.) Torr.	Buckleya, piratebush
Comandra umbellata (L.) Nutt.	Comandra, bastard toadflax
Nestronia umbellula Raf.	Nestronia
Pyrularia pubera Michx.	Buffalo nut, oilnut
Scrophulariaceae **(Figwort family)**	
Agalinis	
A. aphylla (Nutt.) Raf.	Leafless gerardia
A. divaricata (Chapm.) Penn.	Gulf gerardia
A. fasciculata (Ell.) Raf.	Fascicled gerardia, beach ger

ilicaulis (Benth.) Penn.	Slender-stemmed gerardia
attingeri (Sm.) Sm.	Gattinger's gerardia
eorgiana (Boynton) Penn.	Georgia gerardia
eterophylla (Nutt.) Sm.	Variable-leaf gerardia
nifolia (Nutt.) Britt.	Perennial gerardia
aritima (Raf.) Raf.	Seaside gerardia
icrophylla (Gray) Sm.	Small-leaf gerardia
btusifolia Raf.	Bluntleaf gerardia
urpurea (L.) Penn.	Purple gerardia
etacea (Walt.) J. F. Gmel.	Bristleleaf gerardia
enella Penn.	Slenderleaf gerardia
enuifolia (Vahl) Raf.	Slender gerardia
irgata Raf.	Stiff gerardia
eolaria	
ava (L.) Farw.	Large false foxglove
randiflora (Benth.) Penn.	Showy false foxglove, big-leaf oakleech
evigata (Raf.) Raf.	Smooth false foxglove
edicularia (L.) Raf.	Fernleaf false foxglove
rginica (L.) Penn.	Downy false foxglove
hnera americana L.	Bluehearts
illeja coccinea (L.) Spreng.	Indian paintbrush
stoma macrophylla (Nutt.) Raf.	Mullein foxglove
anthera flammea (Bartr.) Penn.	Macranthera, orange blackherb
mpyrum lineare Desr.	Cowwheat
cularis	
adensis L.	Common lousewort, wood betony
ceolata Michx.	Lousewort
albea americana L.	Chaffseed
eria	
ssioides F. Gmel.) Blake	Senna seymeria
ctinata Pursh	Combleaf seymeria
nthera auriculata (Michx.) Raf.	Tomanthera

Appendix II
Commercial tree species used in pot studies

Scientific Name	Common Name
Carya illinoensis (Wang.) K. Koch	Pecan
Celtis laevigata Willd.	Sugarberry
Fraxinus pennsylvanica Marsh.	Green ash
Liquidambar styraciflua L.	Sweetgum
Liriodendron tulipifera L.	Yellow-poplar
Nyssa aquatica L.	Water tupelo
Nyssa sylvatica Marsh.	Blackgum
Pinus clausa (Engelm.) Vasey	Sand pine
Pinus echinata Mill.	Shortleaf pine
Pinus elliottii Engelm.	Slash pine
Pinus palustris Mill.	Longleaf pine
Pinus strobus L.	White pine
Pinus taeda L.	Loblolly pine
Platanus occidentalis L.	American sycamore
Populus deltoides Marsh.	Eastern cottonwood
Quercus alba L.	White oak
Quercus falcata Walt.	Southern red oak
Quercus shumardii Buckl.	Shumard oak
Taxodium distichum (L.) Rich.	Baldcypress

pendix III
ustorial attachments by 19 root asites on commercial tree species

	Parasites																		
ost ecies	*Agalinis aphylla*	*Agalinis fasciculata*	*Agalinis linifolia*	*Agalinis purpurea*	*Agalinis setacea*	*Agalinis tenuifolia*	*Aureolaria flava*	*Aureolaria grandiflora*	*Aureolaria laevigata*	*Aureolaria pedicularia*	*Aureolaria virginica*	*Buchnera americana*	*Buckleya distichophylla*	*Dasistoma macrophylla*	*Macranthera flammea*	*Schwalbea americana*	*Seymeria cassioides*	*Seymeria pectinata*	*Ximenia americana*
is	X	X	O	X	X	X	X	X	X	X	X	O	X	X	X	O	X	X	X
a	X	X	X	X	–	X	X	X	O	X	X	X	X	X	X	X	O	X	X
anica	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	O	X	X
ar *a*	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
on	O	X	X	X	–	X	O	X	X	X	X	X	O	X	X	X	X	X	X
	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	O	X	X
	O	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X	X	X	X
a	X	X	X	X	–	X	X	X	X	O	X	X	X	X	X	X	X	O	X
ii	X	X	X	X	–	X	X	X	O	X	X	X	X	X	X	X	X	X	X
r	X	X	X	X	–	X	X	O	O	X	O	X	X	X	X	O	X	X	X
is	X	X	X	X	–	X	X	O	X	X	X	X	X	O	X	X	X	O	X
	X	X	X	X	–	X	X	X	X	X	X	X	X	X	X	X	X	X	X
s *en is*	X	X	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	O
de	X	X	X	X	–	X	X	X	O	X	X	X	X	X	X	O	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X	X
s *a*	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
s *ar*	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
m *hu*	X	X	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X

n
autoria present
gre in height, no haustoria
o ata

Appendix IV
Glossary

ANTHER—The pollen sac of a flower, usually borne on a filament.

AUTOTROPHIC—A plant that produces its own food.

AXIL—Angle between the point of attachment of a leaf and the ster

BRACT—A reduced leaf.

CALYX—Collective term for the sepals.

CAPSULE—A fruit that contains many seeds and splits open at mat

CLEISTOGAMOUS FLOWERS—Flowers that do not open, and ar self-fertilized

COROLLA—Collective term for the petals.

DIOECIOUS—Having male (staminate) and female (pistillate) flow on separate plants.

ENDEMIC—Confined to a restricted area or region.

FASCICLE—Bundle.

FRUIT—A mature ovary containing seeds.

HAUSTORIUM—A modified root that penetrates a host root to for a physiological and morphological bridge between host and parasit

HOLOPARASITE—A parasitic angiosperm that lacks chlorophyll.

INFLORESCENCE—A group of flowers and the manner in which are arranged on an axis.

OVARY—The part of the flower containing embryonic seeds.

ENNATING—Over-wintering, renewing growth each year.

FECT—A flower containing both male and female parts.

AL—Typically the colored portion of the flower, though some ers have colored sepals.

EME—An inflorescence with stalked flowers on an elongated axis.

ZOME—Underground stem.

T PARASITE—A seed plant that parasitizes the roots of neighg plants, usually via haustoria.

BROUS—Rough, sandpaper-like to the touch.

LE—Small, dry leaves or leaf-like structures.

IPARASITE—A parasitic seed plant that contains chlorophyll.

AL—The external part of the flower bud usually persistent at the of the corolla. Typically green but sometimes colored and showy *Comandra*).

MEN—Male reproductive structure with a stalk (filament) and n sac (anther).

LE—The elongated terminal portion of the ovary.

IPATRIC—Overlapping, as in having overlapping ranges.

EXUAL—One sex.

Musselman, L. J. and W. F. Mann, Jr.
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The five families of root parasites of the South are discussed relative to selection of hosts, ecology, and potential for damage to commercial species. An identification key to all genera of root parasites is included. Plants and flowers of 29 species are illustrated and their distribution in the South mapped.

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